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(54) **Liquid crystalline medium and liquid crystal display**

(57) The invention relates to liquid crystalline media comprising a chiral component, component A; a bimesogenic component, component B comprising a bimesogenic compound having a non-symmetric structure; a dielectrically positive component, component C, and/or a dielectrically negative component, component D; and

optionally a dielectrically neutral component, component E; to the use of these liquid crystalline media in liquid crystal devices, in particular in electro-optical devices such as displays, in particular of the flexoelectric type and to such devices.

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Description

Field of the invention

5 [0001] The present invention relates to liquid crystalline media and to liquid crystal displays comprising these media, especially to displays exploiting the flexoelectric effect in chiral nematic liquid crystals and in particular to displays operating in the uniformly lying helix mode.

State of the art and problem to be solved

10 [0002] The flexoelectric effect is well known since quite some time from the paper by Patel and Meyer (Phys. Rev. Lett. 58 (15), p. 1538-1540 (1987)) and has more recently been reviewed by Rudquist et al. (Liq. Cryst. 22 (4), 445-449 (1997)).

15 [0003] The uniform lying helix (ULH) texture is realized using a chiral nematic liquid crystal with a short pitch, typically in the range from 0.2 μm to 1 μm , preferably of 1.0 μm or less, in particular of 0.5 μm or less, which is unidirectionally aligned with its helical axis parallel to the substrates, e. g. glass plates, of a liquid crystal cell. In this configuration the helical axis of the chiral nematic liquid crystal is equivalent to the optical axis of a birefringent plate.

20 [0004] If an electrical field is applied to this configuration normal to the helical axis the optical axis is rotated in the plane of the cell, similar as the director of a ferroelectric liquid crystal rotates in a surface stabilized ferroelectric liquid crystal display. The flexoelectric effect is characterised by fast response times typically ranging from 6 μs to 100 μs . It further features excellent grey scale capability.

25 [0005] The electric field can be understood to essentially flexoelectrically couple to the induced splay-bend deformation of the director. The angle of the rotation of the axis is in first approximation directly and linearly proportional to the strength of the electrical field. The optical effect is best seen when the liquid crystal cell is placed between crossed polarizers with the optical axis in the unpowered state at an angle of 22.5° to the absorption axis of one of the polarizers. This angle of 22.5° is also the ideal angle of rotation of the of the electric field, as thus, by the inversion the electrical field, the optical axis is rotated by 45° and by appropriate selection of the relative orientations of the preferred direction of the axis of the helix, the absorption axis of the polarizer and the direction of the electric field, the the optical axis can be switched from parallel to one polarizer to the center angle between both polarizers. The optimum contrast is then
30 achieved when the total angle of the switching of the optical axis is 45°. In that case the arrangement can be used as a switchable quarter wave plate, provided the optical retardation, i. e. the product of the effective birefringence of the liquid crystal and the cell gap, is selected to be the quarter of the wave length. In this context the wavelength referred to is 550 nm, the wavelength for which the sensitivity of the human eye is highest, unless explicitly stated otherwise.

35 [0006] The angle of rotation of the optical axis (Φ) is given in good approximation by formula (1).

$$\tan \Phi = \bar{e} P_0 E / (2 \pi K) \quad (1)$$

wherein

40 P_0 is the undisturbed pitch of the cholesteric liquid crystal,
 \bar{e} is the average [$\bar{e} = \frac{1}{2} (e_{\text{splay}} + e_{\text{bend}})$] of the splay flexoelectric coefficient (e_{splay}) and the bend flexoelectric coefficient (e_{bend}),
 E is the electrical field strength and
 45 K is the average [$K = \frac{1}{2} (k_{11} + k_{33})$] of the splay elastic constant (k_{11}) and the bend elastic constant (k_{33})

and wherein

\bar{e} / K is called the flexo-elastic ratio.

50 [0007] This angle of rotation is half the switching angle in a flexoelectric switching element.

[0008] The response time (τ) of this electro-optical effect is given in good approximation by formula (2).

$$\tau = [P_0 / (2\pi)]^2 \cdot \gamma / K \quad (2)$$

55

wherein

γ is the effective viscosity coefficient associated with the distortion of the helix.

[0009] There is a critical field (E_c) to unwind the helix, which can be obtained from equation (3).

$$E_c = (\pi^2 / P_0) \cdot [k_{22}/(\epsilon_0 \cdot \Delta\epsilon)]^{1/2} \quad (3)$$

wherein

k_{22} is the twist elastic constant,
 ϵ_0 is the permittivity of vacuum and
 $\Delta\epsilon$ is the dielectric anisotropy of the liquid crystal.

[0010] Liquid Crystal Displays (LCDs) are widely used to display information. Electro-optical modes employed are e.g. the twisted nematic (TN)-, the super twisted nematic (STN)-, the optically compensated bend (OCB)- and the electrically controlled birefringence (ECB)-mode with their various modifications, as well as others. Besides these modes, which all do use an electrical field, which is substantially perpendicular to the substrates, respectively to the liquid crystal layer, there are also electro-optical modes employing an electrical field substantially parallel to the substrates, respectively the liquid crystal layer, like e.g. the In-Plane Switching mode (as disclosed e.g. in DE 40 00 451 and EP 0 588 568). Especially this electrooptical mode is used for LCDs for modern desk top monitors.

[0011] The liquid crystals according to the present invention are preferably used in flexoelectric, chiral nematic devices, preferably in displays or in electrooptical devices like switches for light or optical components.

[0012] Preferably displays according to the present invention are addressed by an active matrix i.e. a matrix of active electrical elements with a nonlinear current - voltage characteristic. These active elements preferably are thin film transistors (TFTs). They can be used for direct view applications as well as for projection type displays.

[0013] A chiral substance mixed with a nematic material induces a helical twist transforming the material into a chiral nematic material, which is equivalent to a cholesteric material. The terms chiral nematic and cholesteric are used synonymously in this application, unless explicitly stated otherwise. One difference between a cholesteric material and a chiral nematic material, however, is the fact, that the cholesteric pitch of the latter can be varied over a rather large range with comparative ease. The pitch induced by the chiral substance is in a first approximation inversely proportional to the concentration of the chiral material used. The constant of proportionality of this relation is called the helical twisting power (HTP) of the chiral substance and defined by equation (4)

$$HTP \equiv 1 / (c \cdot P_0) \quad (4)$$

wherein

c is concentration of the chiral compound.

[0014] For these displays new liquid crystalline media with improved properties are required. Especially the birefringence (Δn) should be optimised for the optical mode. I.e. the optical retardation ($d \cdot \Delta n$) should be preferably such that the equation (5)

$$\sin^2(\pi \cdot d \cdot \Delta n / \lambda) = 1 \quad (5)$$

wherein

d is the cell gap and
 λ is the wave length of light

is satisfied. The allowance of deviation for the right hand side of equation (5) is +/- 3%.

[0015] The wave length of light generally referred to in this application is 550 nm, unless explicitly specified otherwise.

[0016] The cell gap of the cells preferably is in the range from 1 μm to 20 μm , in particular with in the range from 2.0 μm to 10 μm .

[0017] Further, on the one hand, the dielectric anisotropy ($\Delta\epsilon$) should be high enough to allow the coupling of the

electrical field during orientation of the chiral nematic liquid crystal, but, on the other hand, at the same time it should be as small as possible, to prevent unwinding of the helix upon application of the addressing voltage. Preferably $\Delta\epsilon$ should be higher than 0 and very preferably be 0.1 or more; but preferably 10 or less, more preferably 7 or less and most preferably 5 or less. Besides these parameters, the media have to exhibit a suitably wide range of the nematic phase, a rather small rotational viscosity and an at least moderately high specific resistivity.

[0018] The displays according to the present invention are preferably addressed by an active matrix (active matrix LCDs, short AMDs), preferably by a matrix of thin film transistors (TFTs). However, the inventive liquid crystals can also beneficially be used in displays with other known addressing means.

[0019] Liquid crystal compositions with short cholesteric pitch for flexoelectric devices are known from EP 0 971 016, GB 2 356 629 and Coles, H.J., Musgrave, B., Coles, M.J., and Willmott, J., J. Mater. Chem., 11, p. 2709-2716 (2001). EP 0 971 016 discloses mesogenic estradiols, which, as such, have a high flexoelectric coefficient. GB 2 356 629 discloses bimesogenic compounds and their use in flexoelectric devices. The flexoelectric effect has been investigated in pure cholesteric liquid crystal compounds and in mixtures of homologous compounds only so far. Most of these compounds were used in binary mixtures consisting of a chiral additive and a nematic liquid crystal material being either a simple, conventional monomesogenic material or a bimesogenic one. These materials do have several drawbacks for practical applications, like insufficiently wide temperature ranges of the chiral nematic - or cholesteric phase, too small flexoelectric ratios, small angles of rotation.

[0020] The cyanobiphenyl-based bimesogens have low solubility and are nematic at high temperatures (e.g. the switching behaviour of CBO8OCB + 3% BDH-1281 can only be investigated above 168°C). Therefore, they are not suitable for practical applications since they cannot be used in room temperature displays (see J. Mater. Chem., 11, p. 2709-2716 (2001)).

The monomesogenic materials exhibit good solubility properties but in chiral-doped systems, the helix unwinds at low voltages (e.g. for 7CB + 4% BDH-1305, the maximum tilt angle is 6° before the helix unwinds at about 20V for a 4µm thick cell). Furthermore, the investigations on these systems were performed at relatively high relative temperatures which are only slightly below the respective clearing points of the materials, typically about 12°C below the clearing point.

[0021] Similar difficulties were encountered with the pure cholesteric materials such as the homologous series of estradiols. These are not liquid crystalline at room temperature and additionally, the maximum rotation angles achieved are only 10° or less.

[0022] Furthermore, there has been a problem to achieve the orientation of cholesteric liquid crystals in the uniaxially lying helix texture in a well reproducible way. Coles et al., J. Mater. Chem., 2001, 11, pp. 2709-2716, mentioned above, reports that monomesogenic liquid crystals containing a chiral additive, which exhibit blue phases promote the easy formation of the uniaxially lying helix texture. When such materials are enclosed in liquid crystal cells between two walls, at least one of which is provided with an alignment layer for planar alignment, they spontaneously form a uniformly lying helix texture upon application of an alternating electrical field across the material while it is in its blue phase. Subsequently the sample is cooled into the cholesteric phase under the applied field. In this case no mechanical manipulation, like shearing the liquid crystal sample, is required to obtain the uniform alignment. However, this reference only discloses only cholesteric liquid crystal materials based on monomesogenic liquid crystal materials but does not even mention bimesogenic liquid crystals.

[0023] It further has been reported by Blatch et al., J. Mater. Chem., 1997, 7(1), pp. 9-17, that liquid crystal materials comprising bimesogenic liquid crystals with an odd number of atoms in the spacer group, which are further comprising a chiral centre sufficient to achieve a helical pitch of 500 nm or less, do generally exhibit blue phases.

[0024] Thus, there is a significant need for liquid crystalline media with suitable properties for practical applications such as e.g. computer monitors, screens for television sets and the like, displays for multi media applications, hand held tele-communication devices, automatic teller machines and light modulators. They have to have a wide nematic phase range, low viscosities, a high $\Delta\epsilon$, a sufficiently high resistivity and, in particular, an appropriately optimised optical anisotropy Δn for a given cell thickness depending on the display mode used.

Present invention

[0025] Surprisingly, it now has been found that liquid crystalline media with a sufficiently wide range of the chiral nematic phase and suitably high flexo-elastic ratio and sufficiently short response time can be realised using a liquid crystal medium comprising

- a chiral component, component A;
- a bimesogenic component, component B;
- a dielectrically positive component, component C and/or a dielectrically negative component, component D;

that is characterized in that

[0026] These media according to the present invention do not exhibit the drawbacks of the materials of the prior art or at least do exhibit them to a significantly lesser degree.

[0028] The base mixtures preferably have a positive dielectric anisotropy, in order to further the alignment of the axis of the helix in the plane of the cell. However, at the same time, the dielectric anisotropy of the base mixture has to be limited, as otherwise there would be an undesired unwinding of the helix upon application of the electrical field instead of the desired switching of the axis of the helix. The dielectric anisotropy of the base mixture preferably is in the range from 0 or more to 10 or less and especially preferably 8.0 or less and in particular from 0 or more to 6.0 or less, preferably from 0 or more, preferably 0.1 or more to 5 or less.

[0030] In this application the terms room temperature and ambient temperature refer to a temperature of 20°C, unless explicitly stated otherwise.

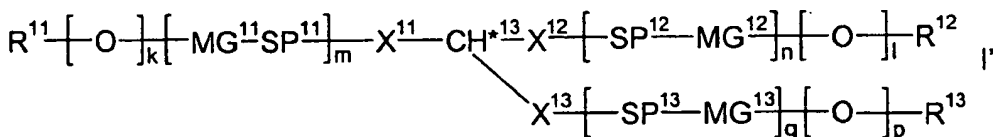
[0032] The unwinding voltage for the helical structure of the mixture is typically 30V or more, preferably 50V or more, more preferably 70V or more and especially 75V or more at room temperature for a 5µm thick cell.

[0034] It is preferred that a dielectrically neutral component, component E is present the liquid crystal medium of the invention.

[0035] It is further preferred that said component B of the liquid crystal medium according to the invention comprises a bismesogenic compound having a non-symmetric structure and an odd number of atoms in the spacer group between the two mesogenic units.

[0036] Furthermore, the liquid crystal medium of the invention preferably comprises both a dielectrically negative component, component D and a dielectrically neutral component, component E.

[0037] With regard to the chiral component, component A it is preferred that said component is a mesogenic component, preferably consisting of chiral compounds, preferably comprising one or more compounds selected from the group of formulae I, I' and I''



5

R¹¹, R¹² and R¹³

are each, independently of one another, F, Cl, CN, NO₂, NCS, SCN, OCN, a straight-chain or branched alkyl group with 1 to 25 C atoms which may be unsubstituted, mono- or polysubstituted by halogen or CN, it being also possible for one or more non-adjacent CH₂ groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, -N(CH₃)-, -CO-, -COO-, -OCO-, -OCOO-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CH-, -CF=CF- or -C≡C- in such a manner, that oxygen atoms are not linked directly to one another, or, in case they are not linked to an O atom, H;

Y

SP¹¹, SP¹² and SP¹³

has the meaning given for R¹¹ and is preferably H, F, CH₃ or CF₃, more preferably H or F; are each, independently of one another, a divalent spacer group comprising 1 to 40, preferably 4 to 20, C atoms, preferably an alkylene group, it being also possible for one or more CH₂ groups in the spacer groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, -N(CH₃)-, -CO-, -COO-, -OCO-, -OCOO-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CH-, -CF=CF-, -CF₂- or -C≡C- in such a manner, that oxygen atoms are not linked directly to one another;

SP¹⁴ and SP¹⁵

are each, independently of one another, a divalent spacer group comprising 1 to 40, preferably 4 to 20, C atoms;

X¹¹, X¹² and X¹³

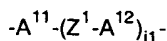
are each, independently of one another, -O-, -S-, -CO-, -COO-, -OCO-, -OCOO-, -CO-NH-, -NH-CO-, -CH₂CH₂-, -OCH₂-, -CH₂O-, -SCH₂-, -CH₂S-, -CF=CF-, -CH=CH-, -OCO-CH=CH-, -C≡C- or a single bond;

k, l, n, m, p and q
m+n+q

are each, independently of one another, 0 or 1, with m being preferably 1, is 1, 2 or 3, for formula I preferably 2, for formula I' preferably 1 and for formula I'' preferably 2 or 3 and most preferably 2;

MG¹¹, MG¹² and MG¹³

are each, independently of one another, a mesogenic group, preferably of the formula I'''



I'''

wherein

A¹¹ and A¹²

are each, independently of one another, a bivalent ring group containing preferably at least four C atoms, preferably a five- or a six- membered ring and preferably has the meaning given for ring A³¹ under formula III below;

Z¹

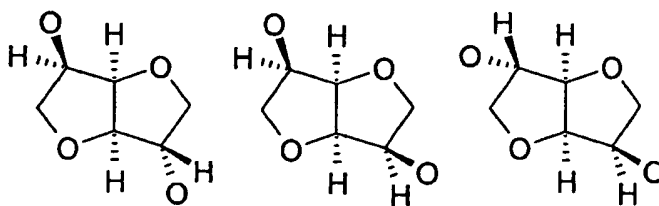
each have, independently of one another, the meaning given for Z³¹ under formula III below; and

i1

is 0, 1 or 2, preferably 0 or 1;

CH*¹¹

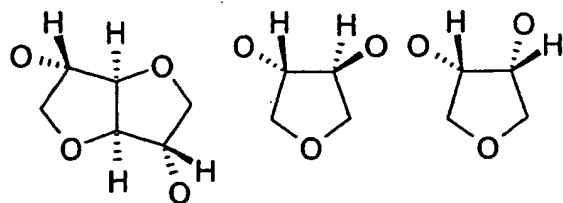
is a chiral, bivalent group, preferably with a chiral center or with one or more chiral atoms preferably selected from the group of formulae Ia to In



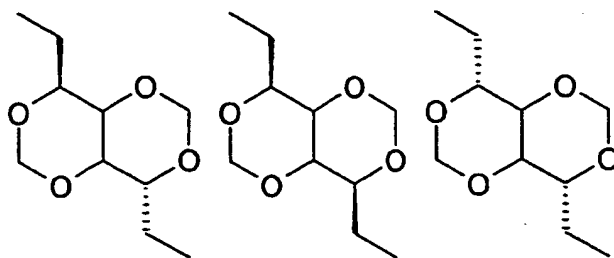
Ia

Ib

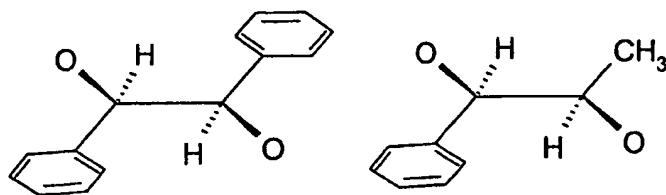
Ic



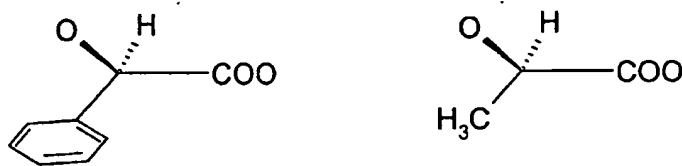
Id , le , lf ,



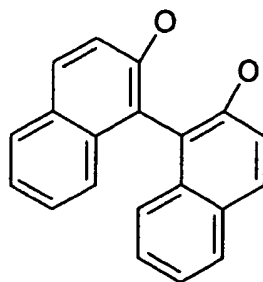
lg , lh , li ,



lj , lk ,



ll , lm ,



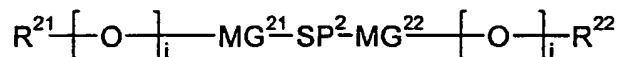
[0038] In , or their mirror images, if not depicted;

CH*¹² is a chiral, bivalent group, preferably with a chiral center or with one or more chiral atoms preferably selected from the group of formulae Ie, If and In, or their mirror images, if not depicted, especially preferred In; and

CH*¹³ is a chiral, trivalent group, preferably with a chiral center or with one or more chiral atoms preferably -CH=, -CF=, -C(CH₃)=, -C(OCH₃)= or -C(CF₃)=;

where in all groups Ia to Ik, and especially preferred in the aromatic rings of groups Ij, Ik, Il and In, optionally one or more hydrogen atoms can be replaced by further aromatic rings, aliphatic rings, alkyl chains, alkoxy chains, alkenyl chains and alkenyloxy chains, which all may be substituted by halogen atoms, especially fluorine, or CN.

[0039] With regard to the bimesogenic component, component B, of the liquid crystal medium according to the invention said component is preferably a mesogenic component preferably consisting of bimesogenic compounds, preferably comprising one or more compounds of formula II,



II

wherein

R²¹ and R²² are each, independently of one another, F, Cl, CN, NO₂, NCS, SCN, OCN, a straight-chain or branched alkyl group with 1 to 25 C atoms which may be unsubstituted, mono- or polysubstituted by halogen or CN, it being also possible for one or more non-adjacent CH₂ groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, -N(CH₃)-, -CO-, -COO-, -OCO-, -OCOO-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CH-, -CF=CF- or -C≡C- in such a manner, that oxygen atoms are not linked directly to one another, or, in case they are not linked to an O atom, H;

MG²¹ and MG²² are each, independently of one another, a mesogenic group and have preferably the meaning given for MG¹¹ under formula I above,

SP² is a divalent spacer group comprising 1 to 40, preferably 3 to 20, C atoms, preferably an alkylene group, it being also possible for one or more CH₂ groups in the spacer groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, -N(CH₃)-, -CO-, -COO-, -OCO-, -OCOO-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CH-, -CF=CF-, -CF₂- or -C≡C- in such a manner, that oxygen atoms are not linked directly to one another;

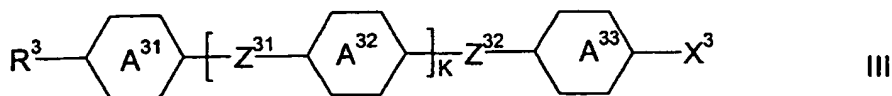
i and j are, independently of each other, 0 or 1;

whereby the moiety R²¹-[-O-]_i-MG²¹ is different from the moiety R²²-[-O-]_j-MG²², i.e. the compound of formula II is non-symmetric.

[0040] Besides said at least one non-symmetric bimesogenic compound component B may also comprise one or more bimesogenic compounds having a symmetric structure. These symmetric bimesogens preferably have a structure similar to those of formula II with the exception that the moiety R²¹-[-O-]_i-MG²¹ is not different from the moiety R²²-[-

O-]-MG²².

[0041] With regard to the dielectrically positive component, component C it is preferred that said component is consisting of dielectrically positive compounds, preferably comprising one or more compounds of formula III and, optionally, further dielectrically positive compounds

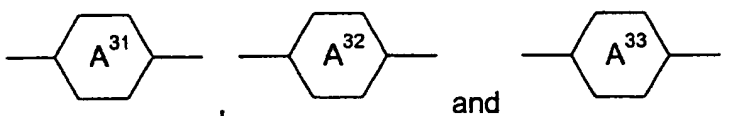


wherein

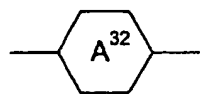
R³ is H, F, alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy with 1 to 7 C-atoms, alkenyl, alkenyloxy, alkoxyalkyl or fluorinated alkenyl with 2 to 7 C-atoms;

X³ H, CN, NCS, F, Cl or fluorinated alkyl or fluorinated alkoxy, each with 1 to 4 C-atoms, preferably CN, OCF₃, OCF₂H, F or Cl, most preferably OCF₃ or H;

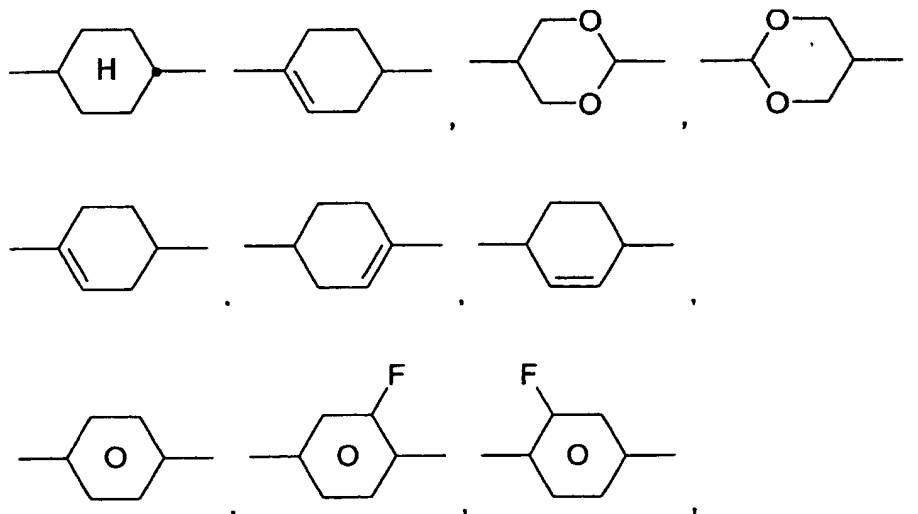
Z³¹ and Z³², independently of each other, and in case Z³¹ is present twice, also these independently of each other, are -CH₂-CH₂-, -CF₂-CF₂-, -CF₂-O-, -O-CF₂-, -CO-O- or a single bond, preferably -CH₂-CH₂-, -CO-O- or a single bond;

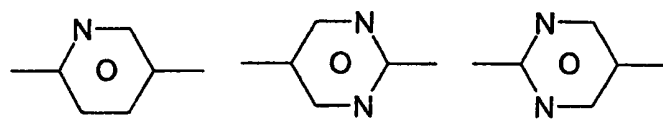
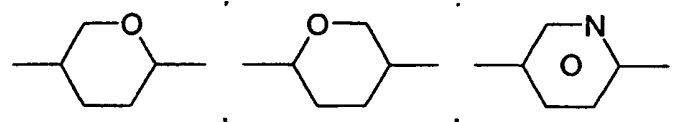
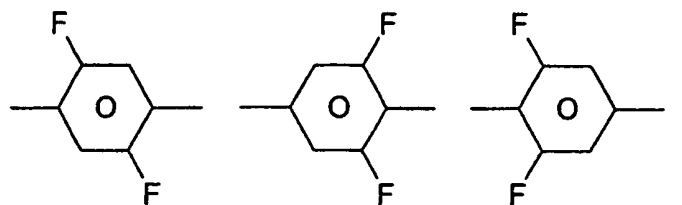


independently of each other, and in case

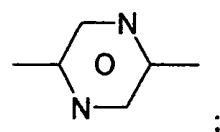


is present twice, also these independently of each other, are





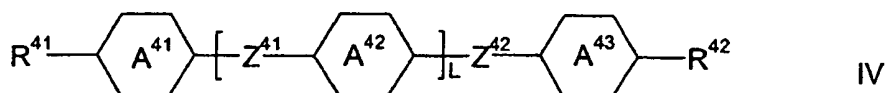
or



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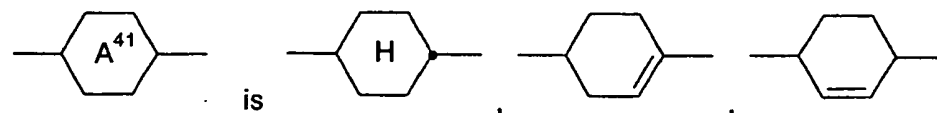
30 K is 0, 1 or 2, preferably 0 or 1.

[0042] With regard to the dielectrically negative component, component D of the present invention, it is present optionally, preferably obligatorily, and consisting of dielectrically negative compounds, preferably comprising one or more compounds of formula IV

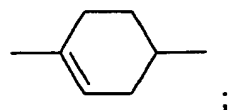


wherein

45 R^{41} and R^{42} independently of each other have the meaning given for R^3 under formula III above;

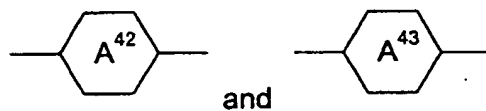


or



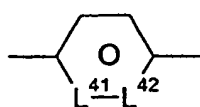
;

one of

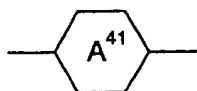


and

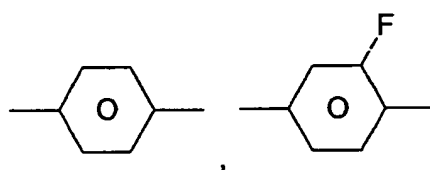
is



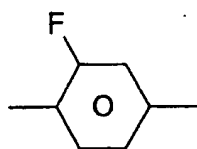
and the other one has, or the other two, independently of each other, have the same meaning, or one of the meanings given for



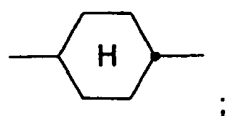
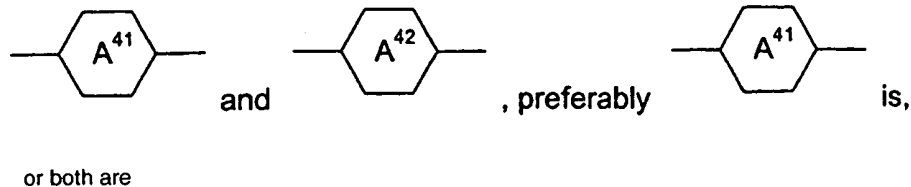
or are



or



optionally one of

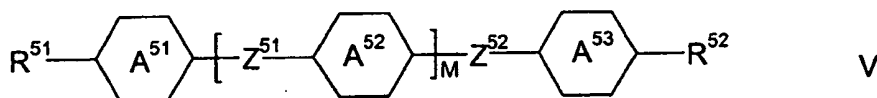


L⁴¹ and L⁴² are, independently of each other, =C(-F)- or =N-, preferably at least one of them is =C(-F)- and, most preferably, both of them are =C(-F)-;

20 Z⁴¹ and Z⁴² are, independently of each other, -CH₂CH₂-, -COO-, trans- CH=CH-, trans- -CF=CF-, -CH₂O-, -CF₂O- or a single bond, preferably at least one of them is a single bond and most preferably both are a single bond; and

L is 0 or 1 or 2, preferably 0 or 1.

25 **[0043]** With regard to the dielectrically neutral component, component E being optionally, preferably obligatorily, present in the liquid crystal medium according to the invention said component is consisting of dielectrically neutral compounds, preferably comprising one or more compounds of formula V



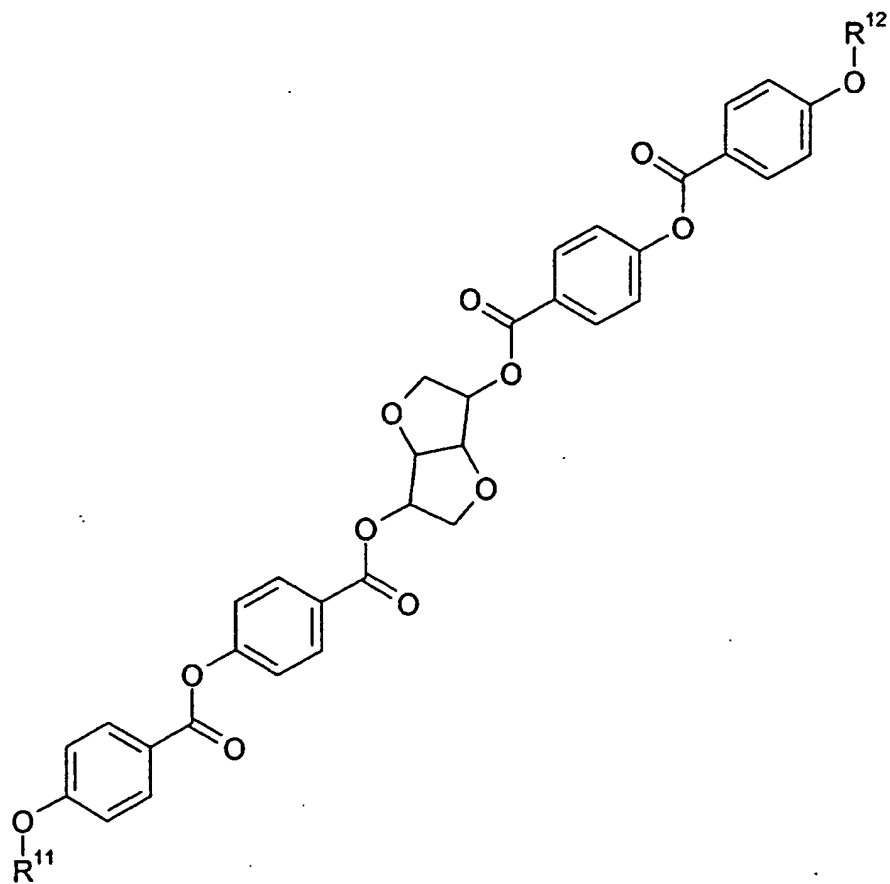
35 wherein

R⁵¹ and R⁵² independently of each other, have the meaning given for R³ under formula III above;
 the rings A⁵¹, A⁵² and A⁵³, independently of each other, have the meaning given for ring A³¹ under formula III above;

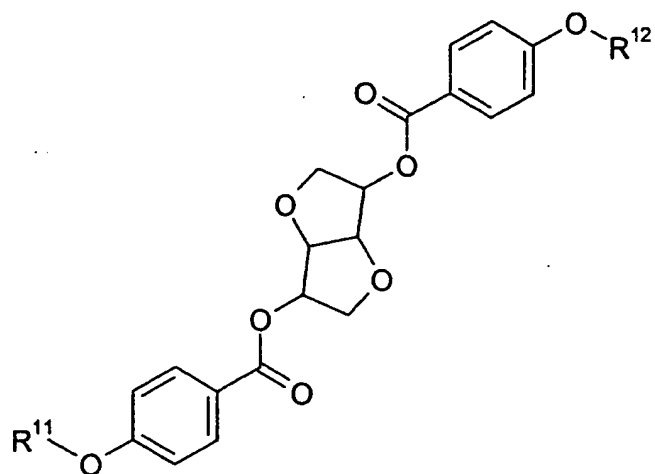
40 Z⁵¹ and Z⁵², independently of each other, have the meaning given for Z³¹ under formula III above;
 and

M is 0 or 1 or 2, preferably 0 or 1.

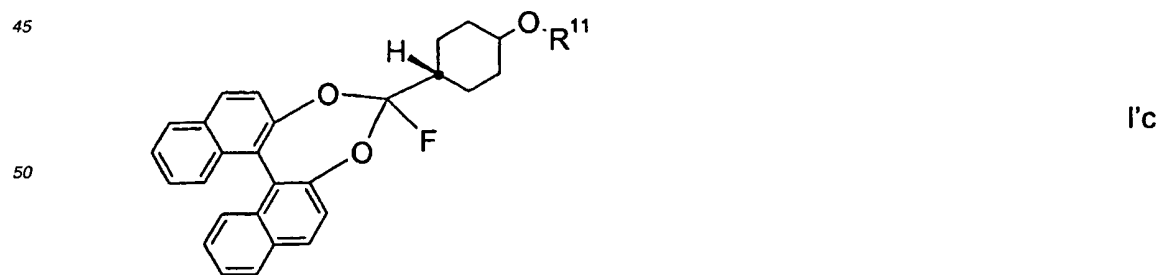
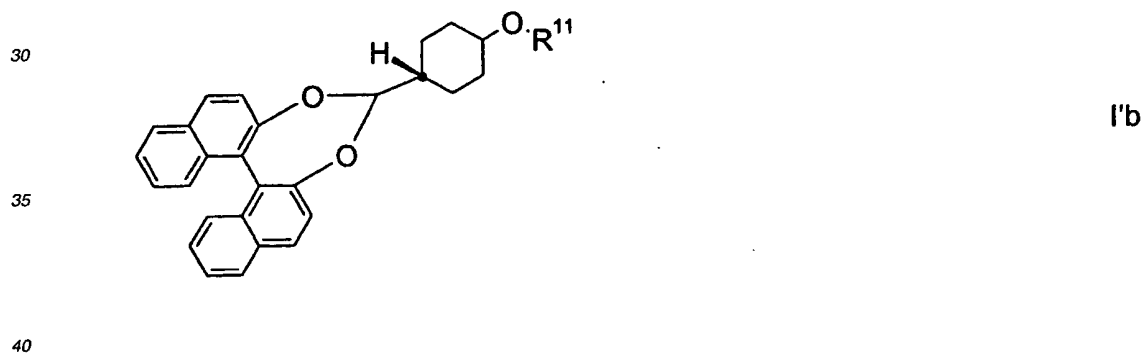
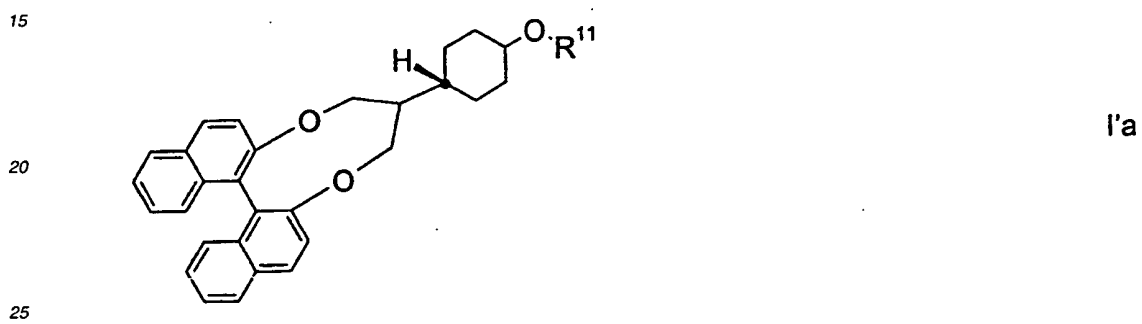
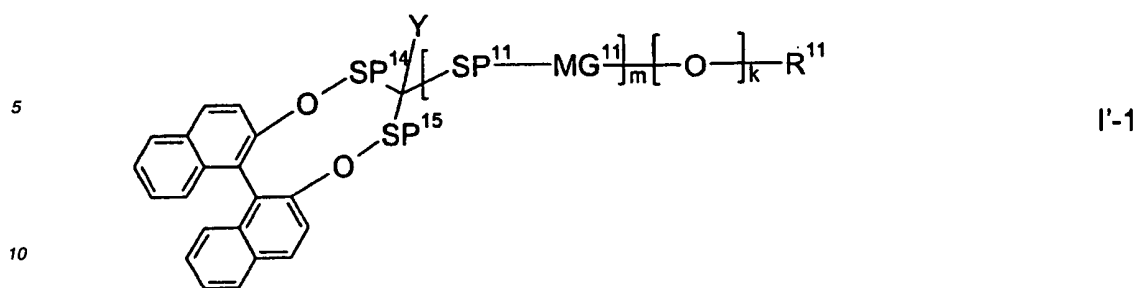
45 **[0044]** Preferably the chiral component, component A comprises one or more compounds selected from the group of formulae Ia, Ib and I'-1, preferably of its sub-formulae I'a to I'c, preferably one or more compounds each of at least two different formulae selected from this group of formulae



1a



1b

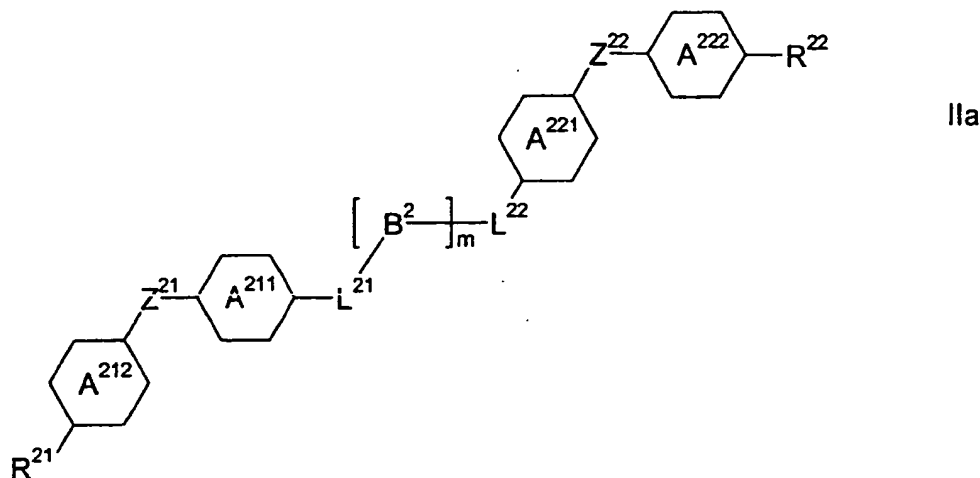


wherein the parameters have the respective meanings given under formula I above and preferably

R¹¹ and R¹² are, independently of each other, alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy with 1 to 7 C-

atoms, alkenyl, alkenyloxy, alkoxyalkyl or fluorinated alkenyl with 2 to 7 C-atoms.

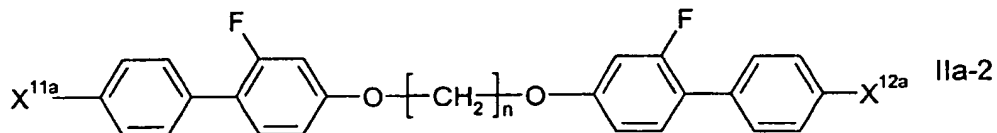
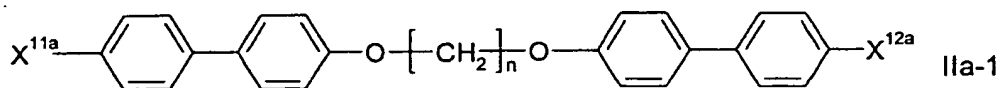
[0045] Preferably the bimesogenic component, component B comprises one or more compounds of formula IIa, preferably one or more compounds each of at least two different formulae selected from this group of formulae

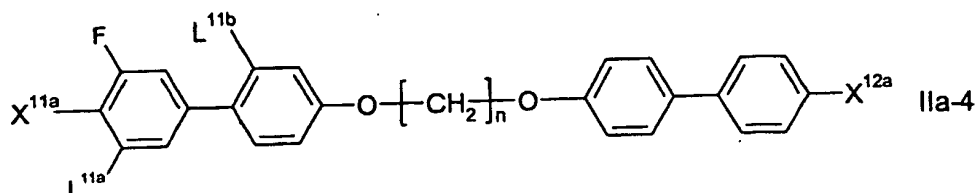
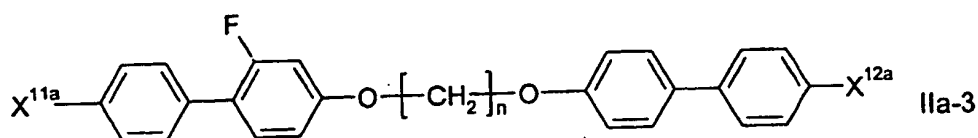


wherein

R^{21} and R^{22} , independently of each other have the meaning given under formula II above;
the rings A^{211} , A^{212} , A^{221} and A^{222} , independently of each other have the meaning given for ring A^{31} under formula III above;
 Z^{21} and Z^{22} , independently of each other have the meaning given for Z^{31} under formula III above;
 L^{21} and L^{22} , independently of each other have the same meaning as given for X^{11} under formula I, I' or I'' above;
 B^2 is CH_2 , CFH , CF_2 or if present more than once any combination thereof, preferably CH_2 ; and
 m is an integer from 1 to 19, preferably from 3 to 17 and most preferably from 5 to 13; it is especially preferred that m is an odd number.

[0046] Especially preferred are compounds of formulae IIa-1, IIa-2, IIa-3 and IIa-4:





20 wherein

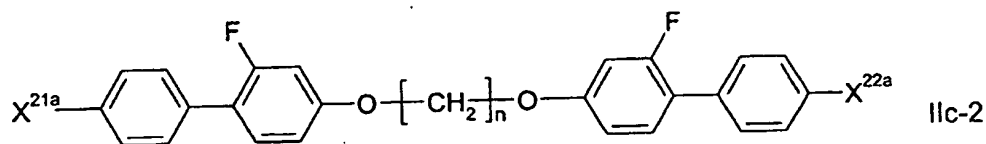
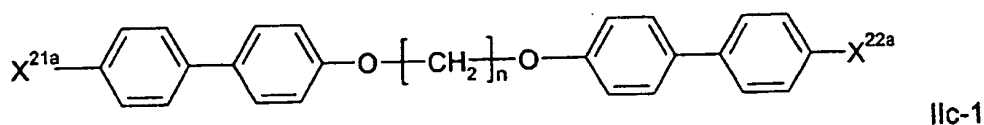
25 X^{11a} and X^{12a} , independently of each other are CN, F, Cl or fluorinated alkyl or fluorinated alkoxy, each with 1 to 4 C-atoms, preferably CN, CF_3 , F or Cl, more preferably CN, F or Cl, most preferably CN or F, whereby in formulae IIa-1 and IIa-2 X^{11a} and X^{12a} are different from each other;

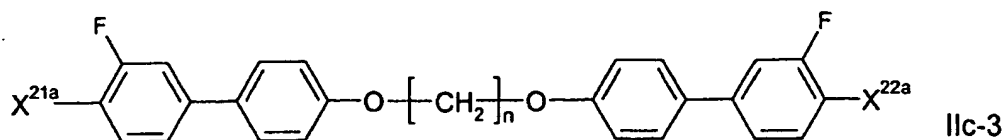
L^{11a} and L^{11b} independently of each other are H or F; and

n is an odd integer in the range from 3 to 17, preferably from 5 to 13.

30 **[0047]** Optionally the bimesogenic component, component B comprises one or more compounds selected from the group of formulae IIb-1 to IIb-4, which are almost identical with the respective formulae IIa-1 to IIa-4 given above, wherein the parameters have the meanings given above, which, however are different in that X^{11a} and X^{12a} are identical in formulae IIa-1 and IIa-2 and/or n is an even integer in the range from 2 to 18.

35 **[0048]** Preferably the bimesogenic component, component B comprises one or more compounds of formula IIc, preferably one or more compounds each of at least two different formulae selected from the group of formulae IIc-1, IIc-2 and IIc-3

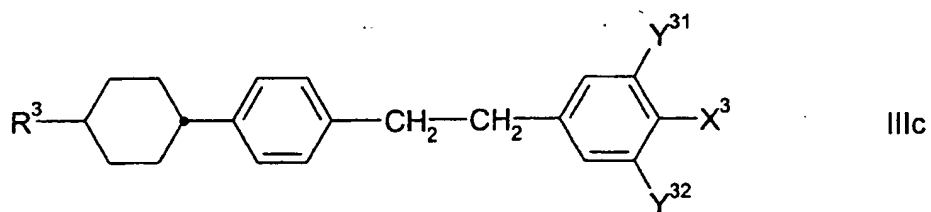
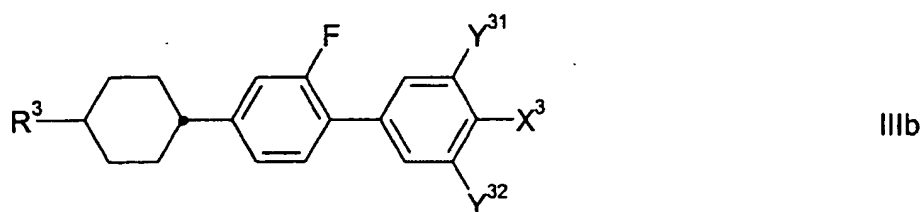
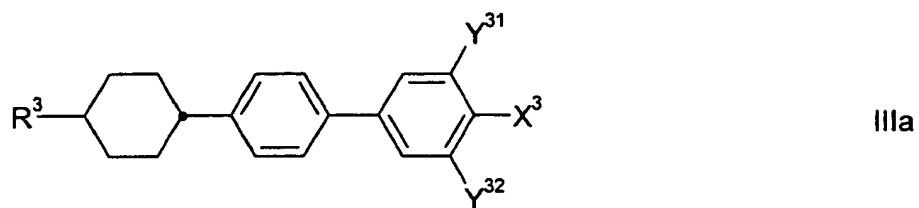


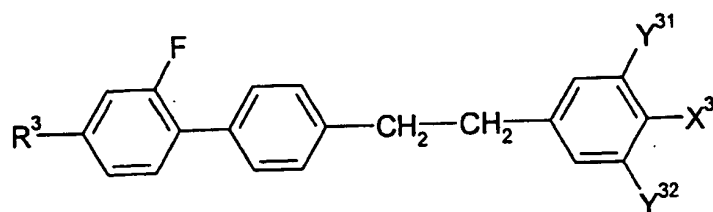


wherein

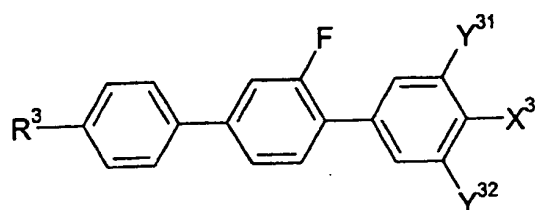
10 X^{21a} and X^{22a} , have the meaning given for X^{11a} and X^{12a} under formulae IIb-1 to IIb-3 above; and
 n is an integer in the range from 2 to 18.

15 **[0049]** Preferably the dielectrically positive component, component C comprises one or more compounds selected from the group of formulae IIIa to IIIg, preferably one or more compounds each of at least two different formulae selected from this group of formulae

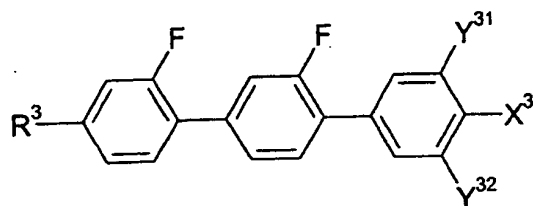




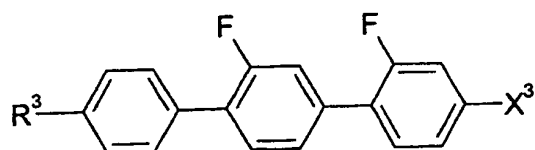
IIIId



IIIe



IIIf



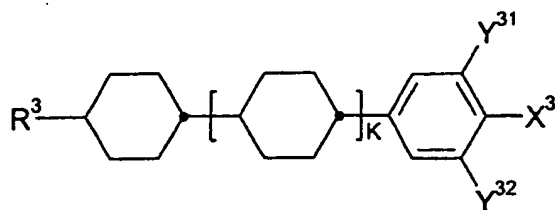
IIIg

wherein

R^3 is alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy with 1 to 7 C-atoms, alkenyl, alkenyloxy, alkoxyalkyl or fluorinated alkenyl with 2 to 7 C-atoms;
 X^3 is F, Cl or fluorinated alkyl or fluorinated alkoxy, each with 1 to 4 C-atoms, preferably OCF_3 , OCF_2H , F or Cl, most preferably F; and
 Y^{31} and Y^{32} are, independently of each other H or F;

wherein, optionally, two of the 6-membered rings shown directly linked, may be linked by a group selected from $-CH_2-CH_2-$, $-CF_2-CF_2-$, $-CF_2-O-$, $-O-CF_2-$ and $-CO-O-$, preferably $-CH_2-CH_2-$ and $-CF_2-O-$, most preferably $-CH_2-CH_2-$.

[0050] Further, the dielectrically positive component, component C optionally comprises one or more compounds of formula IIIh



IIIh

wherein

15 R^3 is alkyl, alkoxy, fluorinated alkyl or fluorinated alkoxy with 1 to 7 C-atoms, alkenyl, alkenyloxy, alkoxyalkyl or fluorinated alkenyl with 2 to 7 C-atoms;

X^3 is F, Cl or fluorinated alkyl or fluorinated alkoxy, each with 1 to 4 C-atoms, preferably OCF_3 , OCF_2H , F or Cl, most preferably F;

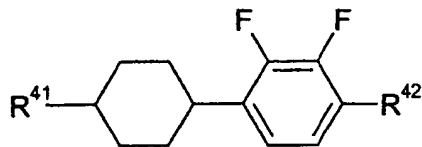
Y^{31} and Y^{32} are, independently of each other H or F; and

20 K is 0, 1 or 2, preferably 0 or 1 and most preferably 1;

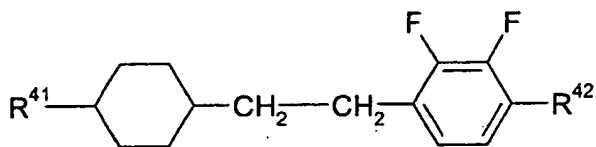
wherein, optionally, two of the 6-membered rings may be linked by a group selected from

$-CH_2-CH_2-$, $-CF_2-CF_2-$, $-CF_2-O-$, $-O-CF_2-$ and $-CO-O-$, preferably $-CH_2-CH_2-$ and $-CF_2-O-$, most preferably $-CH_2-CH_2-$.

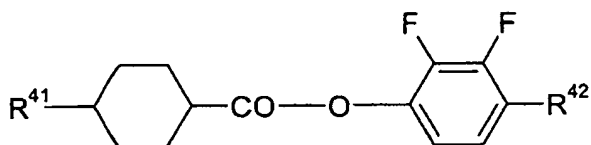
25 **[0051]** The liquid crystal mixtures according to the present invention preferably comprise a dielectrically negative component, component D. This component has a dielectrical anisotropy of -1.5 or less, preferably in the range from -1.5 to -8. Preferably it contains essentially and especially preferably consists entirely of dielectrically negative compounds. Preferably this component comprises one or more dielectrically negative compounds selected from the group of formulae IVa to IVh



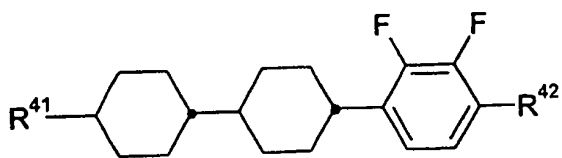
IVa



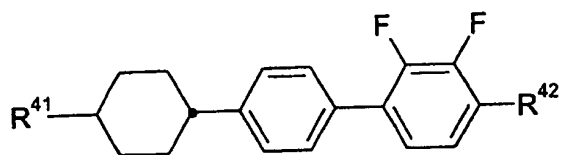
IVb



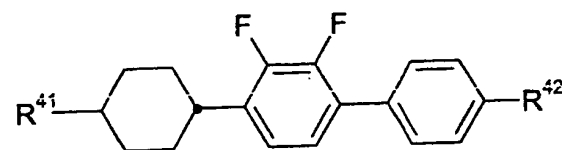
IVc



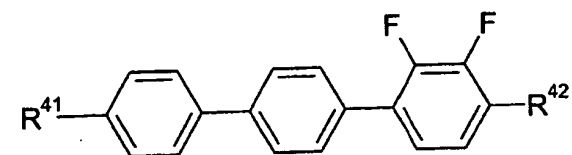
IVd



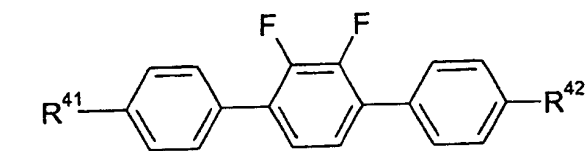
IVe



IVf



IVg

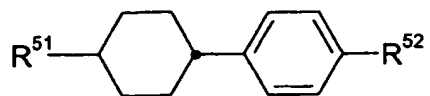


IVh

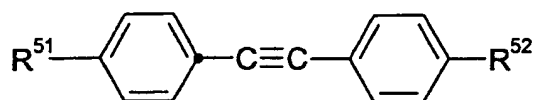
wherein

30 R⁴¹ and R⁴² have the respective meaning given under formula IV above.

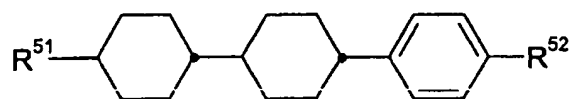
[0052] The liquid crystal mixtures according to the present invention preferably comprise a dielectrically neutral component, component E. This component has a dielectrical anisotropy in the range from -1.5 to +3.0. Preferably it contains essentially and especially preferably consists entirely of dielectrically neutral compounds. Preferably this component comprises one or more dielectrically neutral compounds selected from the group of formulae Va to Vm



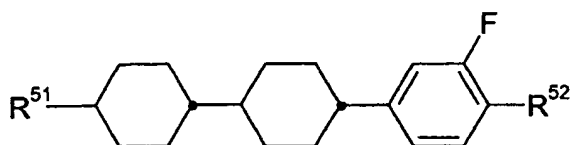
V a



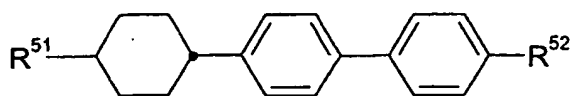
V b



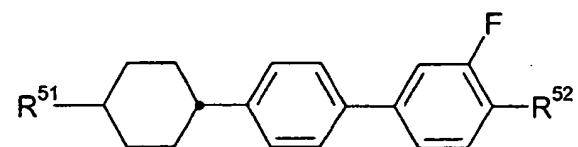
V c



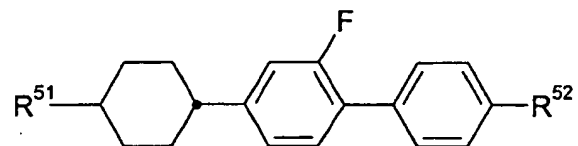
V d



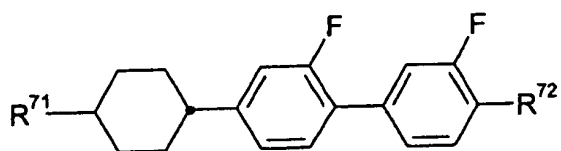
V e



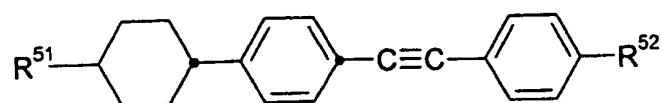
V f



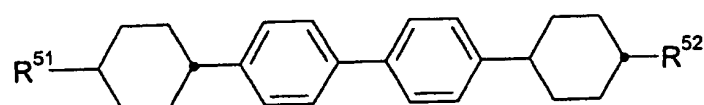
V g



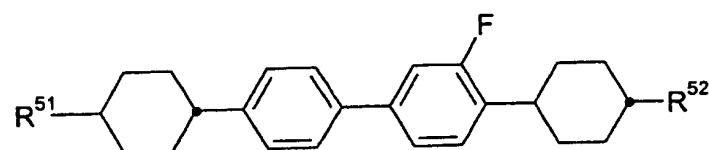
V h



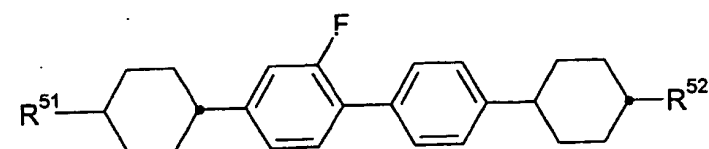
V i



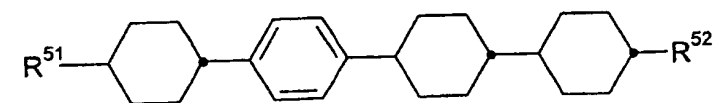
V j



V k



V l



V m

35

wherein

40 R^{51} and R^{52} have the respective meaning given under formula V above.

45 1st embodiment

50 [0053] The improved liquid crystalline media according to the first preferred embodiment of the instant invention comprise a chiral component (component A), a bimesogenic component (component B), a dielectric positive component (component C), and a dielectric negative component (component D). In this embodiment the components A, C and D

and the optional component E can be regarded as representing the host mixture for the bimesogenic component (component B).

2nd embodiment

[0054] In a second embodiment of the instant invention, which may be identical to the first embodiment or different from that, an improvement is achieved with respect to the angles of rotation and the flexoelectric properties for flexoelectric devices at ambient temperature. In this embodiment the liquid crystalline media comprise a chiral compound (component A), bimesogens (component B), positive dielectric anisotropy compounds (component C), optionally, preferably obligatorily, neutral compounds (component E) and optionally negative dielectric anisotropy compounds (component D).

3rd embodiment

[0055] The third embodiment of the instant invention, which is independent from the two previous embodiments, but synergistically supplements them, resides in the chiral additive used. The chiral structure in liquid crystalline nematics for flexoelectric devices is achieved by adding chiral dopants. Significant improvement was obtained when binaphthol based compounds were used to replace isosorbides in terms of solubility and operating temperature range. To achieve a pitch suitable for flexoelectric devices, the chiral dopant concentration is preferably from 0.5% or more to 10% or less, more preferably from 1 % or more to 5% or less and most preferably from 1.5% or more to 4% or less and especially 2% or more.

[0056] Additional improvement is obtained in low temperature stability when binaphthol dopants, preferably of formula I'a, are used compared to isosorbide dopants. Preferably the compounds of formula I' are selected from the group of formulae I'a, I'b and I'c.

[0057] The chiral nematic phase extends to preferably less than 20°C or less, more preferably 15°C or less, most preferably 10°C or less, especially 5°C or less.

[0058] The present invention is also directed to a liquid crystal device comprising a liquid crystal medium according to the invention. Preferably, said device is an electro-optical display. In an especially preferred embodiment said device comprises a display that comprises

- a pair of substrates
 - each substrate bearing one or more electrodes; and
 - one substrate bearing an orientation layer for planar alignment of liquid crystals or being otherwise treated for planar orientation of liquid crystals; and
 - the other substrate bearing an orientation layer for homeotropic alignment of liquid crystals or being otherwise treated for homeotropic alignment of liquid crystals
- and
- a liquid crystal material comprising the liquid crystal medium according to the invention and as set forth in any one of claims 1 to 6;
 - whereby said material is aligned in a uniformly lying helix structure with a helical pitch in the range from 100 nm to 800 nm, preferably from 200 nm to 600 nm and most preferably in the range from 250 nm to 500 nm.

[0059] In a preferred embodiment of the present invention the helical pitch is 500 nm or less, preferably lower than 400 nm, most preferably lower than 300 nm or less.

[0060] The liquid crystal material to be used in the liquid crystal device of the present invention preferably exhibits a blue phase. This allows that the orientation of said liquid crystal material in said uniformly lying helix structure is achieved by application of an alternating electrical field at a temperature at which the liquid crystal material is in the blue phase; by cooling said liquid crystal material being in the blue phase under the applied field finally the display is obtained in which the liquid crystal material is aligned in the uniformly lying helix structure as given above.

[0061] Preferably the liquid crystalline materials used in the displays according to the present invention have an induced chiral nematic phase.

[0062] The chiral nematic liquid crystalline media can also be aligned in the ULH texture upon application of an alternating electrical field by using an intrinsically non-symmetric system.

[0063] This non-symmetry can be easily introduced into the system in different ways. In one preferred embodiment the inner surfaces of the substrates of the display are treated to align liquid crystals in a hybrid alignment. This means that one surface induces planar alignment, also called homogeneous alignment, whereas the other surface induces

homeotropic alignment. Obviously in both alignments the liquid crystals may exhibit a finite surface tilt angle.

[0064] These displays according to the present invention do not exhibit the drawbacks of the displays of the prior art or at least do exhibit them to a significantly lesser degree.

[0065] In a further preferred embodiment of the instant invention, which may be different from the embodiment described above, the alternating electrical field applied to align the liquid crystal material is preferably lower than the critical field for helix unwinding. For practical reasons it is preferably $12 \text{ V}/\mu\text{m}$ or less and most preferably $4 \text{ V}/\mu\text{m}$ or less.

[0066] In a further preferred embodiment of the instant invention, which may be different from the embodiments described above, a liquid crystal cell with surfaces treated for planar or for hybrid alignment, preferably for hybrid alignment, is used. In this embodiment the preferred starting condition for the orientation of the liquid crystal material is the Grandjean texture and the system preferably is at a temperature of 20° , more preferably 10° and most preferably 3° below the chiral ??? In this embodiment, which is independent from the two previous embodiments, the strength of the aligning field is applied, ramped up and / or increased gradually at the critical field only for the helix unwinding. This allows for true homeotropic alignment in case the liquid crystal material has a positive dielectric anisotropy, which is generally preferred in this application and especially in the instant embodiment. Then the aligning field is decreased gradually from its maximum value, preferably the critical field, until a good uniform lying helix alignment is achieved, over a defined time span. This time span preferably is in the range of 1 second to 2 hours, more preferably in the range of 1 second to 600 seconds and most preferably in the range from 1 second to 60 seconds. For reasons of productivity the time span should be as short as possible, while a sufficient time has to be allowed to ensure proper orientation.

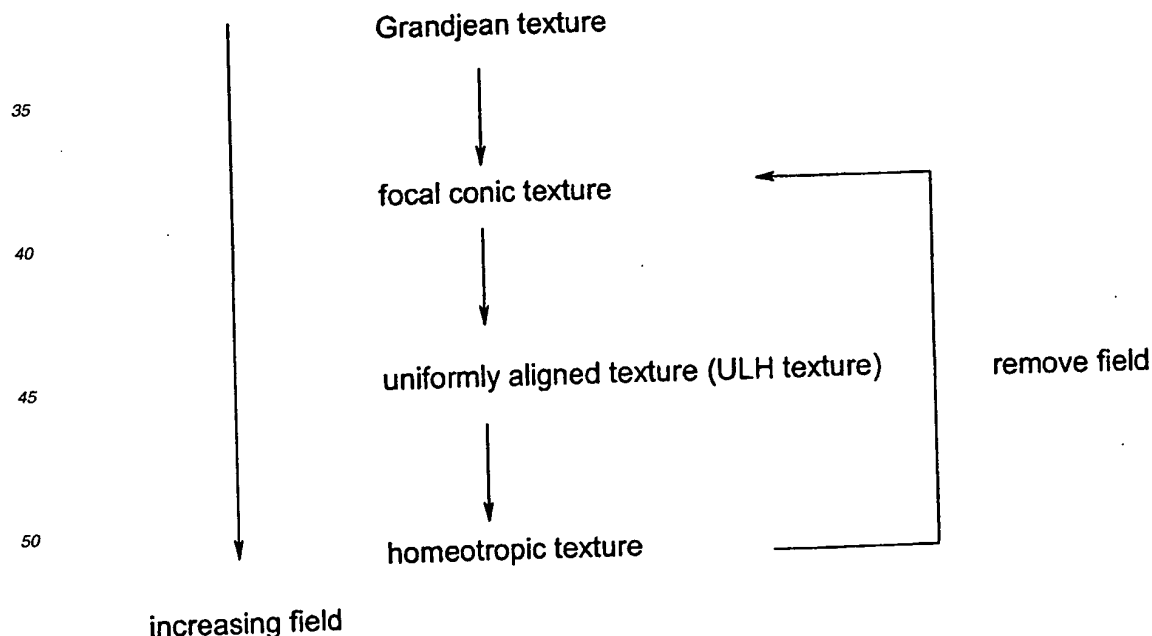
[0067] A sweeping speed of $1.5 \text{ V}/\text{min}$ has been found useful in most cases.

[0068] A sweeping speed per cell gap of $20 \text{ V}/(\mu\text{m}\cdot\text{min})$ and in particular of $1.5 \text{ V}/\text{min}$ has been found useful in most cases.

[0069] The chiral nematic phase of the liquid crystal materials preferably extends over a range of 10 degrees centigrade or more, preferably over a range of 20 degrees centigrade or more and most preferably over a range 30 degrees centigrade or more

[0070] The sequence of textures typically observed in a sample of an inventive medium upon application of an electric field is as follows:

Scheme 1: Phase sequence during orientation



[0071] The liquid crystal base mixture preferably has an elastic constant k_{11} of $1 \cdot 10^{-11} \text{ N}$ or more and the flexoelectric mixture has an average flexoelectric coefficient \bar{e} of $1 \cdot 10^{-11} \text{ C}/\text{m}$ or more, preferably in the range from $1 \cdot 10^{-11} \text{ C}/\text{m}$ to $1 \cdot 10^{-10} \text{ C}/\text{m}$.

[0072] Preferably the liquid crystalline media according to the instant invention are comprising, preferably predominantly consisting of and most preferably entirely consisting of compounds selected from the group of formulae I to V.

[0073] Comprising in this application means in the context of compositions that the entity referred to, e.g. the medium or the component, contains the component or components or the compound or compounds in question, preferably in a total concentration of 10 % or more and most preferably of 20 % or more.

[0074] Predominantly consisting, in this context, means that the entity referred to contains 80 % or more, preferably 90 % or more and most preferably 95 % or more of the component or components or of the compound or compounds in question.

[0075] Entirely consisting, in this context, means that the entity referred to contains 98 % or more, preferably 99 % or more and most preferably 100.0 % of the component or components or of the compound or compounds in question.

[0076] In a preferred embodiment the liquid crystalline media according to the instant invention contain a component A comprising, preferably predominantly consisting of and most preferably entirely consisting of compounds selected from the group of formulae I, I' and I".

[0077] In a further preferred embodiment the liquid crystal media contain a liquid crystal component B, which is preferably predominantly consisting of and most preferably entirely consisting of compounds of formula II, preferably IIa.

[0078] In a further preferred embodiment, which may be identical to the previous preferred embodiment or different from it, the liquid crystal medium contains a liquid crystal component E, which is preferably predominantly consisting of and most preferably entirely consisting of compounds of formula V.

[0079] This component E may be present, and preferably is present, besides components C and D.

[0080] Also other mesogenic, as well as nonmesogenic, compounds, which are not explicitly mentioned above, can optionally and beneficially be used in the media according to the instant invention. Such compounds are known to the expert in the field.

[0081] Component A preferably is used in a concentration from 0.1% to 10%, preferably from 0.5% to 8%, more preferably from 0.5 % to 6 % and most preferably from 0.5 % to 4%, preferably up to 3 % of the total mixture.

[0082] Component B preferably is used in a concentration from 0.1 % to 97 %, preferably from 1 % to 80 %, more preferably from 10 % to 70 % and most preferably from 10 % to 60 % of the total mixture.

[0083] Component C preferably is used in a concentration from 0 % to 97 %, preferably from 1 % to 80 %, more preferably from 1 % to 50 % and most preferably from 5 % to 50 % of the total mixture.

[0084] Component D preferably is used in a concentration from 0 % to 97 %, preferably from 0 % to 90 %, more preferably from 0 % to 70 % and most preferably from 0 % to 60 % of the total mixture.

[0085] Component E preferably is used in a concentration from 0 % to 97%, preferably from 1 % to 80 %, more preferably from 1 % to 50 % and most preferably from 5 % to 30 % of the total mixture.

[0086] Optionally, the inventive media can comprise further liquid crystal compounds in order to adjust the physical properties. Such compounds are known to the expert. Their concentration in the media according to the instant invention is preferably 0 % to 30 %, more preferably 0 % to 20 % and most preferably 0.5 % to 15 %.

[0087] Preferably the liquid crystal medium contains 50 % to 100 %, more preferably 70 % to 100 % and most preferably 80 % to 100 % and in particular 90 % to 100 % totally of components A, B, C, D and E, which contain, preferably predominantly consist of and most preferably entirely consist of one or more of compounds of formulae I to V, respectively.

[0088] The liquid crystal media according to the instant invention are characterized by a clearing point of 70 °C or more, preferably of 80 °C or more and in particular of 87 °C or more.

[0089] The Δn of the liquid crystal media according to the instant invention is 0.050 or more, preferably in the range of 0.060 to 0.200, more preferably in the range of 0.060 to 0.170, most preferably in the range of 0.080 to 0.150 and in particular in the range of 0.080 to 0.138.

[0090] The $\Delta\epsilon$, at 1 kHz and 20 °C, of the liquid crystal media according to the invention is 0 or more, preferably 0.1 or more, most preferably 0.5 or more and in particular 0.6 or more. It is, however, preferably 7.0 or less, more preferably 5.0 or less and most preferably 4.0 or less.

[0091] Preferably the nematic phase of the inventive media extends at least from 0°C to 70°C, more preferably at least from -20 °C to 80 °C, more preferably at least from -20 °C to 90 °C, most preferably at least from -30 °C to 90 °C and in particular at least from -30°C to 100 °C, wherein at least means that preferably the lower limit is under cut, wherein the upper limit is surpassed.

[0092] In the present application the term dielectrically positive compounds describes compounds with $\Delta\epsilon > 3.0$, dielectrically neutral compounds are compounds with $-1.5 \leq \Delta\epsilon \leq 3.0$ and dielectrically negative compounds are compounds with $\Delta\epsilon < -1.5$. The same holds for components. $\Delta\epsilon$ is determined at 1 kHz and 20 °C. The dielectrical anisotropies of the compounds is determined from the results of a solution of 10 % of the individual compounds in a nematic host mixture. The capacities of these test mixtures are determined both in a cell with homeotropic and with homogeneous alignment. The cell gap of both types of cells is approximately 10 μm . The voltage applied is a rectangular wave with a frequency of 1 kHz and a root mean square value typically of 0.5 V to 1.0 V, however, it is always selected

to be below the capacitive threshold of the respective test mixture.

[0093] For dielectrically positive compounds the mixture ZLI-4792 and for dielectrically neutral, as well as for dielectrically negative compounds, the mixture ZLI-3086, both of Merck KGaA, Germany are used as host mixture, respectively. The dielectric permittivities of the compounds are determined from the change of the respective values of the host mixture upon addition of the compounds of interest and are extrapolated to a concentration of the compounds of interest of 100 %. Components having a nematic phase at the measurement temperature of 20 °C are measured as such, all others are treated like compounds.

[0094] The term threshold voltage refers in the instant application to the optical threshold and is given for 10 % relative contrast (V_{10}) and the term saturation voltage refers to the optical saturation and is given for 90 % relative contrast (V_{90}) both, if not explicitly stated otherwise. The capacitive threshold voltage (V_0 , also called Freedericksz-threshold V_{Fr}) is only used if explicitly mentioned.

[0095] The ranges of parameters given in this application are all including the limiting values, unless explicitly stated otherwise.

[0096] Throughout this application, unless explicitly stated otherwise, all concentrations are given in mass percent and relate to the respective complete mixture, all temperatures are given in degrees centigrade (Celsius) and all differences of temperatures in degrees centigrade. All physical properties have been and are determined according to "Merck Liquid Crystals, Physical Properties of Liquid Crystals", Status Nov. 1997, Merck KGaA, Germany and are given for a temperature of 20 °C, unless explicitly stated otherwise. The optical anisotropy (Δn) is determined at a wavelength of 589.3 nm. The dielectric anisotropy ($\Delta \epsilon$) is determined at a frequency of 1 kHz. The threshold voltages, as well as all other electro-optical properties have been determined with test cells prepared at Merck KGaA, Germany. The test cells for the determination of $\Delta \epsilon$ had a cell gap of 22 μm . The electrode was a circular ITO electrode with an area of 1.13 cm^2 and a guard ring. The orientation layers were lecithin for homeotropic orientation ($e||$) and polyimide AL-1054 from Japan Synthetic Rubber for homogeneous orientation (s_{\perp}). The capacities were determined with a frequency response analyser Solatron 1260 using a sine wave with a voltage of 0.3 V_{rms} . The light used in the electro-optical measurements was white light. The experimental set up used, consisted of a polarising Olympus microscope equipped with a fast photodiode, whose output signal was monitored on an oscilloscope. External electric fields were applied.

[0097] The liquid crystal media according to the present invention can contain further additives and chiral dopants in usual concentrations. The total concentration of these further constituents is in the range of 0% to 10%, preferably 0.1 % to 6 %, based on the total mixture. The concentrations of the individual compounds used each are preferably in the range of 0.1 % to 3 %. The concentration of these and of similar additives is not taken into consideration for the values and ranges of the concentrations of the liquid crystal components and compounds of the liquid crystal media in this application.

[0098] The inventive liquid crystal media according to the present invention consist of several compounds, preferably of 3 to 30, more preferably of 8 to 20 and most preferably of 10 to 16 compounds.

[0099] These compounds are mixed in conventional way. As a rule, the required amount of the compound used in the smaller amount is dissolved in the compound used in the greater amount. In case the temperature is above the clearing point of the compound used in the higher concentration, it is particularly easy to observe completion of the process of dissolution. It is, however, also possible to prepare the media by other conventional ways, e. g. using so called pre-mixtures, which can be e. g. homologous or eutectic mixtures of compounds or using so called multi-bottle-systems, the constituents of which are ready to use mixtures themselves.

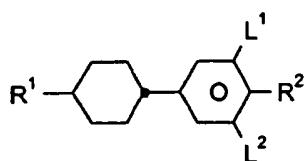
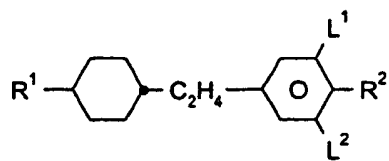
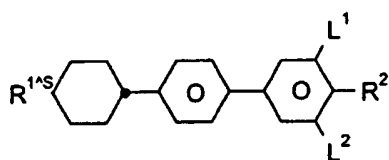
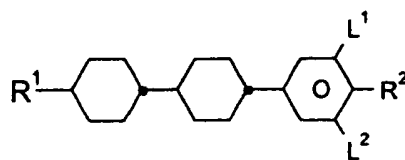
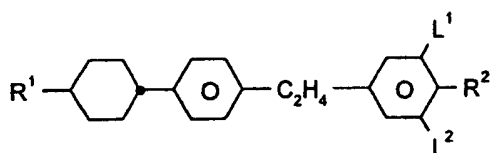
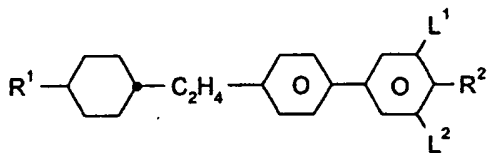
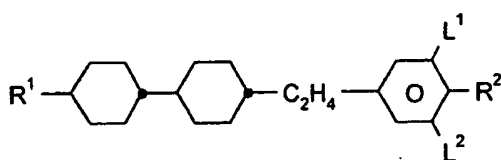
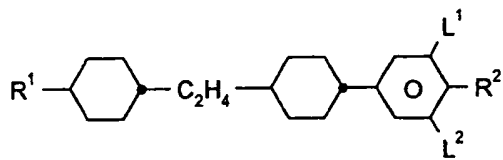
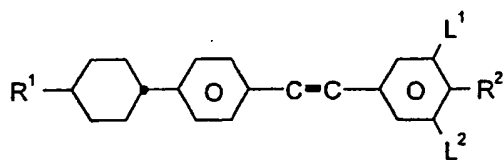
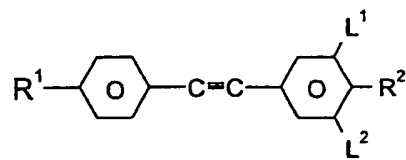
[0100] By addition of suitable additives, the liquid crystal media according to the instant invention can be modified in such a way, that they are usable in all known types of liquid crystal displays, either using the liquid crystal media as such, like TN-, TN-AMD, ECB-AMD, VAN-AMD, IPS and OCB LCDs and in particular in composite systems, like PDLC, NCAP, PN LCDs and especially in projectoin type TFT displays.

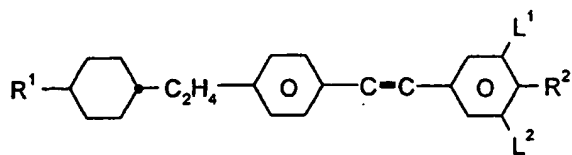
[0101] The orientation of the liquid crystal media according to the present invention in the inventive cells is typically achieved by treating the major inner surfaces of the cell opposing each other with an aligning means for homogeneous alignment and application of an electrical field to the foilled cell. The means for homeotropic orientation is an inorganic layer with a preferred direction, like e.g. obliquely evaporated SiO_x or an organic layer, typically a polymeric layer, having a preferred direction, like an unidirectionally rubbed polyimide or polyamide film.

[0102] The melting point $T(C,N)$, the transition from the smectic (S) to the nematic (N) phase $T(S,N)$ and the clearing point $T(N,I)$ of the liquid crystals are given in degrees centigrade.

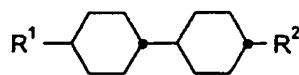
[0103] In the present application and especially in the following examples, the structures of the liquid crystal compounds are represented by abbreviations also called acronyms. The transformation of the abbreviations into the corresponding structures is straight forward according to the following two tables A and B. All groups C_nH_{2n+1} and C_mH_{2m+1} are straight chain alkyl groups with n respectively m C-atoms. The interpretation of table B is self evident. Table A does only list the abbreviations for the cores of the structures. The individual compounds are denoted by the abbreviation of the core followed by a hyphen and a code specifying the substituents R^1 , R^2 , L^1 and L^2 as follows:

Code for R ¹ , R ² , L ¹ , L ²	R ¹	R ₂	L ¹	L ₂
nm	C _n H _{2n+1}	C _m H _{2m+1}	H	H
nOm	C _n H _{2n+1}	OC _m H _{2m+1}	H	H
nO.m	OC _n H _{2n+1}	C _m H _{2m+1}	H	H
n	C _n H _{2n+1}	CN	H	H
nN.F	C _n H _{2n+1}	CN	F	H
nN.F.F	C _n H _{2n+1}	CN	F	F
nF	C _n H _{2n+1}	F	H	H
nF.F	C _n H _{2n+1}	F	F	H
nF.F.F	C _n H _{2n+1}	F	F	F
nOF	OC _n H _{2n+1}	F	H	H
nCl	C _n H _{2n+1}	Cl	H	H
nCl.F	C _n H _{2n+1}	Cl	F	H
nCl.F.F	C _n H _{2n+1}	Cl	F	F
nCF ₃	C _n H _{2n+1}	CF ₃	H	H
nCF ₃ .F	C _n H _{2n+1}	CF ₃	F	H
nCF ₃ .F.F	C _n H _{2n+1}	CF ₃	F	F
nOCF ₃	C _n H _{2n+1}	OCF ₃	H	H
nOCF ₃ .F	C _n H _{2n+1}	OCF ₃	F	H
nOCF ₃ .F.F	C _n H _{2n+1}	OCF ₃	F	F
nOCF ₂	C _n H _{2n+1}	OCHF ₂	H	H
nOCF ₂ .F	C _n H _{2n+1}	OCHF ₂	F	H
nOCF ₂ .F.F	C _n H _{2n+1}	OCHF ₂	F	F
nS	C _n H _{2n+1}	NCS	H	H
nS.F	C _n H _{2n+1}	NCS	F	H
nS.F.F	C _n H _{2n+1}	NCS	F	F
rVsN	C _r H _{2r+1} -CH=CH-C _s H _{2s} -	CN	H	H
rEsN	C _r H _{2r+1} -O-C _s H _{2s} -	CN	H	H
nAm	C _n H _{2n+1}	COOC _m H _{2m+1}	H	H

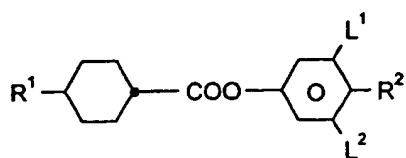
Table A:**PCH****EPCH****BCH****CCP****EBCH****BECH****ECCP****CECP****CPTP****PTP**



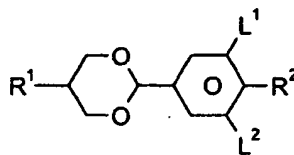
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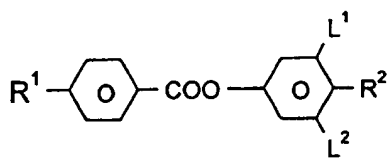
CCH



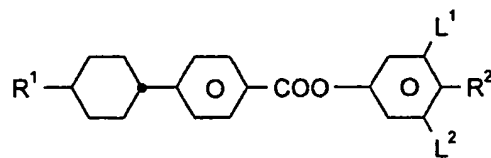
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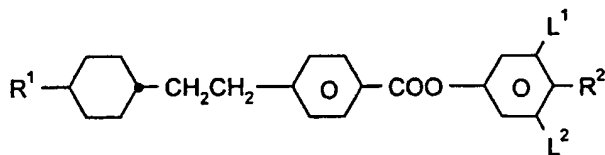
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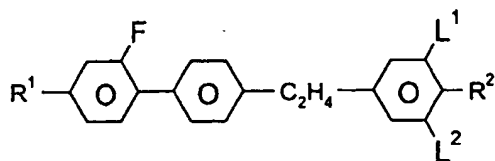
ME



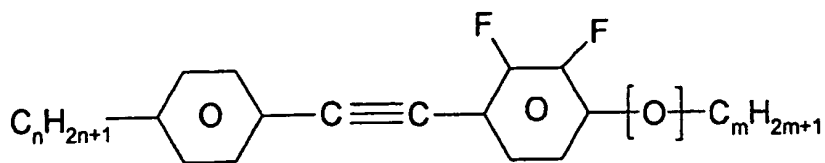
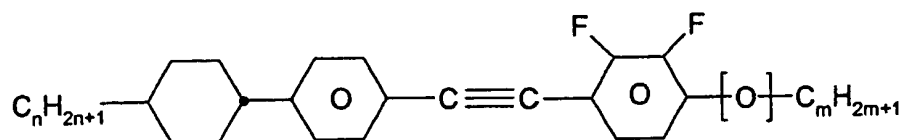
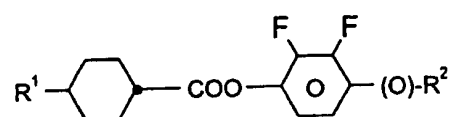
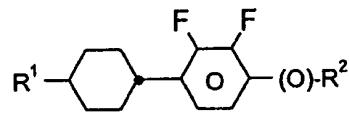
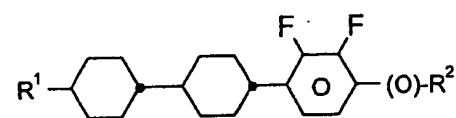
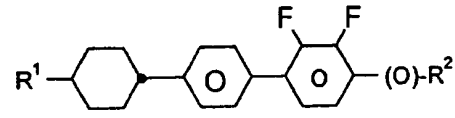
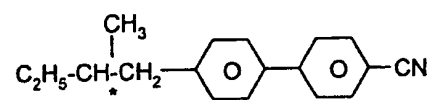
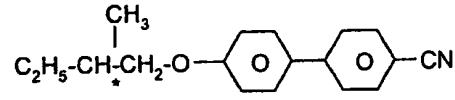
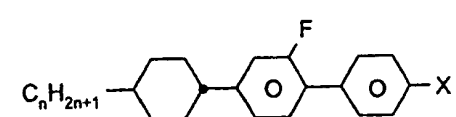
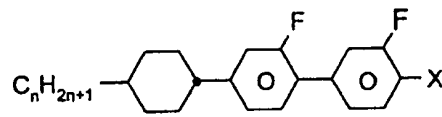
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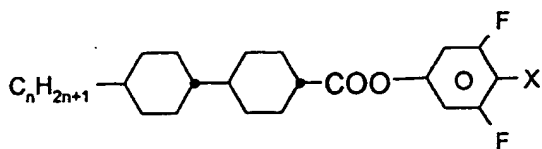
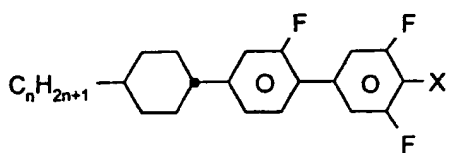
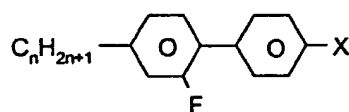
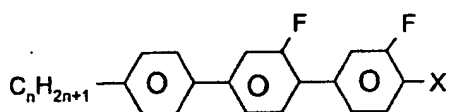
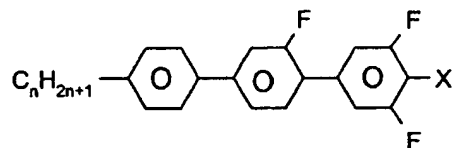
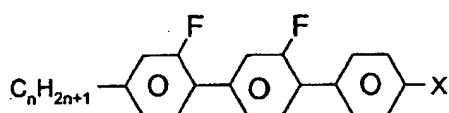
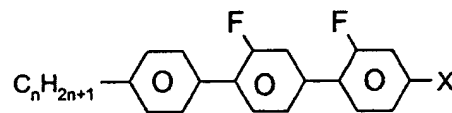
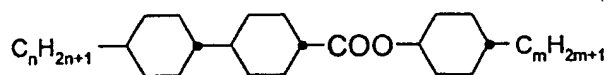


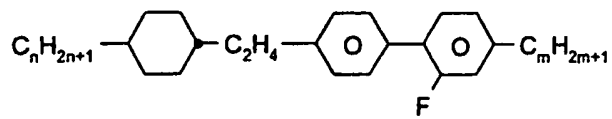
EHP



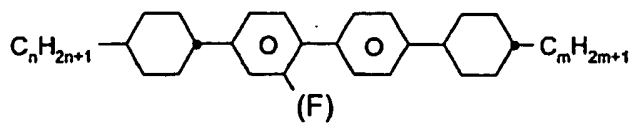
FET

Table B:**PTP-n(O)mFF****CPTP-n(O)mFF****D-n(O)mFF****PCH-n(O)mFF****CCP-n(O)mFF****BCH-n(O)mFF****CB15****C15****CGP-n-X**(X = F, Cl, OCF₃)**CGG-n.FX**(X = F, Cl, OCF₃)

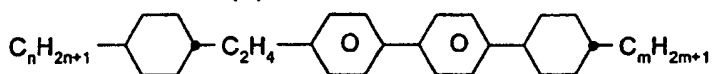
**CCZU-n-X**(X = F, Cl, OCF₃)**CGU-n-X**(X = F, Cl, OCF₃)**GP-n-X**(X = F, Cl, OCF₃)**PGG-n-X**(X = F, Cl, OCF₃)**PGU-n-X**(X = F, Cl, OCF₃)**GGP-n-X**(X = F, Cl, OCF₃)**PGIGI-n-X**(X = F, Cl, OCF₃)**Inm**



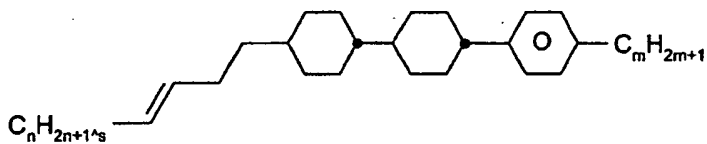
Inm



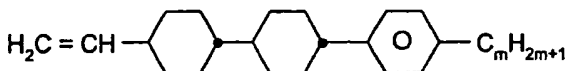
CBC-nm(F)



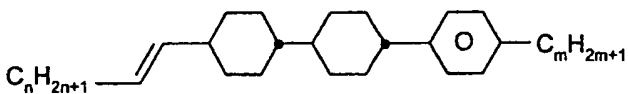
ECBC-nm



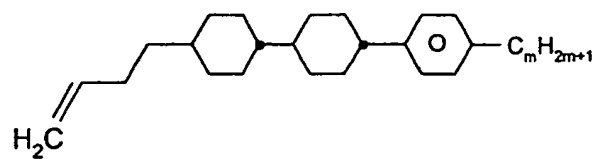
CCP-nV2-m



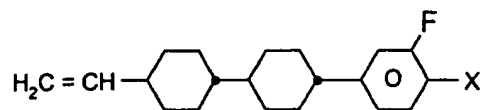
CCP-V-m



CCP-nV-m

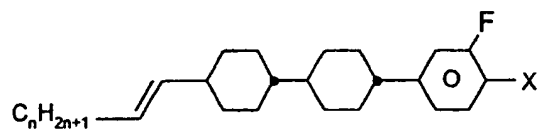


10 **CCP-V2-m**



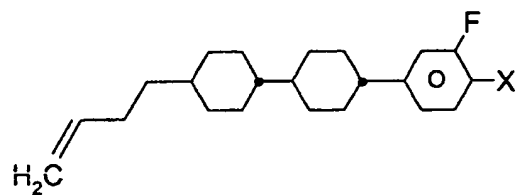
20 **CCG-V-X**

(X = F, Cl, OCF₃)



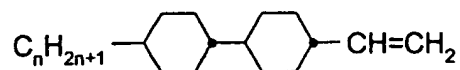
30 **CCG-nV-X**

(X = F, Cl, OCF₃)

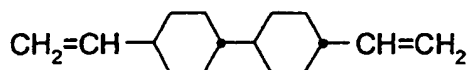


CCP-V2-X

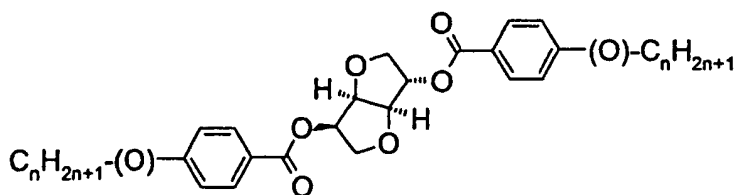
(X = F, Cl, OCF₃)



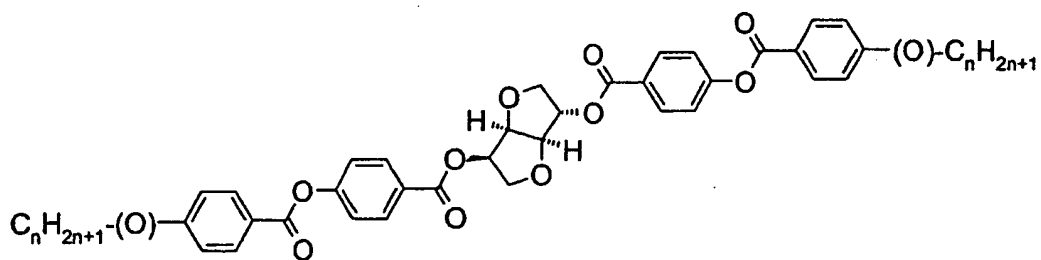
CC-n-V



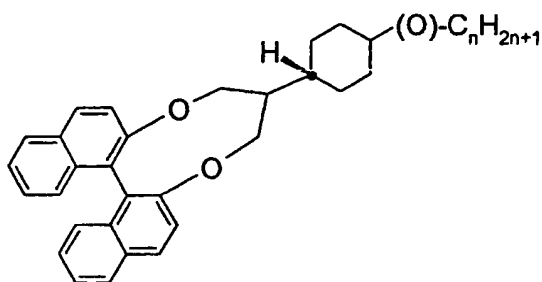
CC-V-V



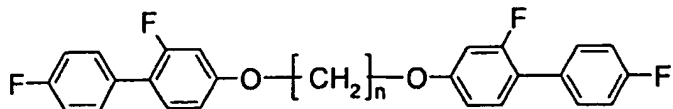
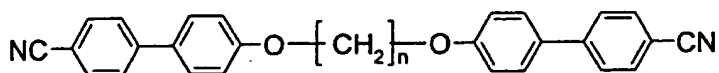
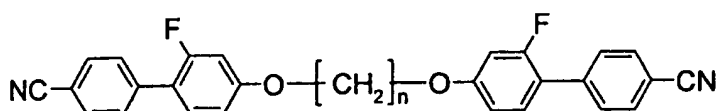
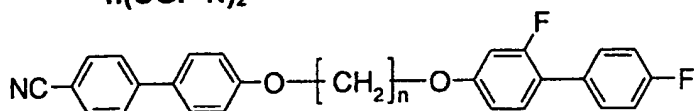
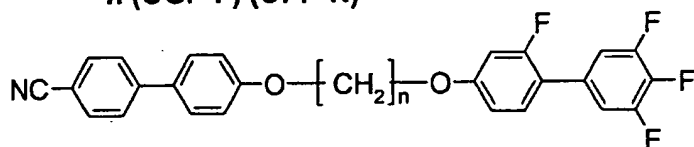
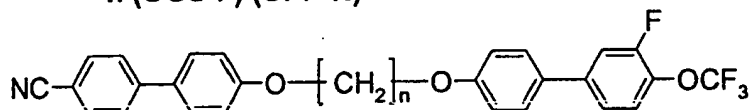
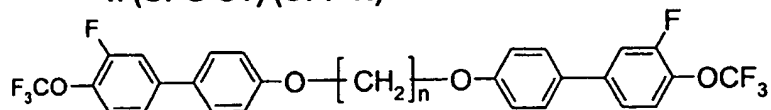
(n(O)-PZ)₂X*



(n(O)-PZPZ)₂X*



n(O)-C1(10)₂N*

**n(OGP-F)₂****n(OPP-N)₂****n(OGP-N)₂****n (OGP-F) (OPP-N)****n (OGU-F) (OPP-N)****n (OPG-OT) (OPP-N)****n (OPG-OT)₂**

[0104] The liquid crystal media according to the instant invention do contain preferably

- three or more, preferably five or more compounds, preferably of different formulae, selected from the group of compounds of formulae of tables A and B and/or
- one, two, three or more, preferably three, four or more compounds, preferably of different formulae, selected from the group of compounds of formulae of table A and/or
- one, two, three or more, preferably two, three or more compounds, preferably of different formulae, selected from

the group of compounds of formulae of table B.

Example 1

- 5 **[0105]** Three nematic liquid-crystal host mixtures A-0 to I-0 of the following compositions are prepared and investigated.

Composition of Mixture A-0		
Compound		Conc.
#	Abbreviation	/Mass-%
1	BCH-3F.F	12.0
2	BCH-5F.F	10.0
3	ECCP-30CF3	5.0
4	ECCP-50CF3	5.0
5	CBC-33F	2.0
6	CBC-53F	2.0
7	CBC-55F	2.0
8	PCH-6F	8.0
9	PCH-7F	6.0
10	CCP-20CF3	8.0
11	CCP-30CF3	12.0
12	CCP-40CF3	7.0
13	CCP-50CF3	11.0
14	PCH-5F	10.0
Σ		100.0

Composition of Mixture B-0		
Compound		Conc.
#	Abbreviation	/Mass-%
1	CCP-2F.F.F	12.0
2	CCP-3F.F.F	12.0
3	CCP-30CF3.F	3.0
4	CCP-20CF3	7.0
5	CCP-30CF3	8.0
6	CCP-50CF3	7.0
7	CGU-2-F	8.0
8	CGU-3-F	9.0
9	CGU-5-F	6.0
10	CCZU-2-F	5.5
11	CCZU-3-F	14.0
12	CCZU-5-F	5.5
13	CBC-33F	3.0
Σ		100.0

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Composition of Mixture C-0		
Compound		Conc.
#	Abbreviation	/Mass-%
1	D-302FF	10.0
2	D-502FF	10.0
3	CCP-302FF	5.0
4	CCP-502FF	6.0
5	PCH-502FF	12.0
6	CCP-21 FF	6.0
7	CCP-31 FF	6.0
8	CH-43	7.0
9	PTP-201	6.0
10	PTP-301	6.0
11	CPTP-301	4.0
12	CPTP-303	4.0
13	CBC-53F	3.0
14	PCH-3	8.0
15	PDX-5	7.0
Σ		100.0

Composition of Mixture D-0		
Compound		Conc.
#	Abbreviation	/Mass-%
1	7(OGP-F) ₂	5.0
2	9(OGP-F) ₂	20.0
3	CCZU-3-F	7.0
4	CCP-30CF3	7.0
5	CCP-50CF3	6.0
6	CCG-V-F	10.0
7	D-302	8.0
8	CC-3-V1	11.0
9	CC-5-V	8.0
10	CCP-V-1	8.0
11	PTP-102	3.0
12	PTP-301	4.0
Σ	PTP-302	3.0
		100.0

Composition of Mixture E-0		
Compound		Conc.
#	Abbreviation	/Mass-%
1	7(OGP-F) ₂	11.0
2	9(OGP-F) ₂	44.0
3	CCZU-3-F	7.0
4	CCP-30CF3	7.0
5	CCP-50CF3	6.0

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(continued)

Composition of Mixture E-0		
Compound		Conc.
#	Abbreviation	/Mass-%
6	D-302	7.0
7	CC-5-V	12.0
8	CBC-33F	3.0
9	CBC-53F	3.0
Σ		100.0

Composition of Mixture F-0		
Compound		Conc.
#	Abbreviation	/Mass-%
1	7(OGP-F) ₂	34.3
2	9(OGP-F) ₂	34.3
3	7(OGU-F)(OPP-N)	14.7
4	9(OGU-F)(OPP-N)	14.7
E		100.0

Composition of Mixture G-0		
Compound		Conc.
#	Abbreviation	/Mass-%
1	7(OGU-F)(OPP-N)	4.9
2	9(OGU-F)(OPP-N)	4.9
3	Mixture A-0	88.2
Σ		100.0

Composition of Mixture H-0		
Compound		Conc.
#	Abbreviation	/Mass-%
1	7(OPG-OT)(OPP-N)	4.9
2	9(OPG-OT)(OPP-N)	4.9
3	Mixture A-0	88.2
Σ		100.0

Composition of Mixture I-0		
Compound		Conc.
#	Abbreviation	/Mass-%
1	7(OGU-F)(OPP-N)	4.9
2	9(OGU-F)(OPP-N)	4.9
3	Mixture B-0	88.2

(continued)

Composition of Mixture I-0		
Compound		Conc.
#	Abbreviation	/Mass-%
Σ		100.0

[0106] The chiral mixtures D-1, E-1 and F-1 are obtained by adding 2% of the chiral binaphthol compound (3C1 (10)₂)N* alternatively to each of the nematic hosts D0, E-0 and F-0, respectively.

[0107] The chiral mixtures G-1, H-1 and I-1 are obtained by adding 2% of the chiral binaphthol compound 3C1 (10)₂ N* alternatively to the each of nematic hosts G-0, H-0 and I-0, respectively.

Example 1.a)

[0108] In this example the alignment of the samples is achieved in the blue phase.

[0109] The uniform lying helix texture forms spontaneously (i.e. no mechanical shearing is required) in a hybrid aligned cell when the chiral LC mixture is cooled from the blue phase in the presence of an ac electric field of amplitude lower than the critical field required to unwind the helix. In this work, this alignment technique is applied to systems consisting of dimers with odd-numbered atoms in the spacer, both of symmetric and of non-symmetric structure and optionally mesogenic compounds having low molecular mass.

[0110] Good uniformly lying helix texture (ULH) has been observed for mixtures D-1, E-1 and I-1. These three samples contain either symmetrical or non-symmetrical dimers with odd spacers in different concentrations. This alignment method also works for the mixture F-1, which contains only symmetric and non-symmetric dimers. The compositions of mixtures are given in tables 1 and 2; the data, such a clearing point and aligning field, are summarised in table 3 for these four samples.

Table 3

Results for mixtures aligned by cooling from the blue phase				
Chiral mixtures	D-1	E-1	I-1	F-1
Host mixture	D-01	E-0	B-0	F-0
$\Delta\epsilon$ of non-chiral host mixture	2.0	2.3	n.d.	n.d.
Chiral compound	3C1(10) ₂)N*			
Cholest. pitch (P) at 30°C / μm	0.415	0.365	0.406	0.449
Clearing point (T(N,I))* /°C	85.4	83.2	79.8	52.2
E_{ULH}^{\S} (V/ μm)	5	6.6	2.4	4
Remarks: *: measured by microscopy on cooling, \S : optimum aligning field for ULH texture, n.d.: not determined. Remarks: n.d.: not determined				

Example 1.b)

[0111] In this example the alignment of the samples is achieved by ramping down the applied electric field.

[0112] Due to the charge gradient induced by an electric field, the uniform lying helix forms spontaneously in a hybrid aligned cell of thickness 5 μm , independent of the cholesteric pitch induced by a chiral dopant when the following procedure is implemented.

1. The system is kept at a temperature preferably 20°, more preferably 10°, most preferably 3° below the temperature of the transition of the chiral mixture from the nematic (cholesteric) to the isotropic phase.

2. After the initial Grandjean texture is formed, the aligning field is ramped up and / or increased gradually above the critical field for the helix unwinding to achieve true homeotropic texture.

3. The aligning field is then decreased gradually from the value above the critical field to 0 V/ μm over a time of preferably 600 minutes, more preferably of 60 minutes, most preferably of 1 minute, for example with a sweeping speed of 1.5 V/min.

[0113] Good alignment in ULH texture is achieved e.g. when this alignment method is applied to:

a) the mixture D-1, which contains about 25% symmetric dimers and

b) the three mixtures G-1, H-1 and I-1, which contain 10% of non-symmetric dimers in different host mixtures such as A-0 and B-0.

[0114] The results are summarised in table 4.

Table 4

Results for mixtures aligned using the decreasing field technique				
Chiral mixtures	D-1	G-1	H-1	I-1
Host mixture	D-0	A-0		B-0
$\Delta\epsilon$ of non-chiral host mixture	2.0	n.d.		n.d.
Chiral compound	3C1(10) ₂ N*			
Cholest. pitch (P) at 30°C μm	0.365	0.480	0.475	0.406
Clearing point (T(N,I))* $^{\circ}\text{C}$	85.4	94.9	97.8	79.8
Temperature (T(Gj.,h)) $^{\circ}\text{C}$	80	91	94.8	77
Electric field E_{homeo} # $\text{N}/\mu\text{m}$	11.8	7.4	7.6	6.1
Remarks: *: measured by microscopy on cooling, #: Electric field for Grandjean-homeotropic transition at T(Gj., h), n.d.: not determined.				

Claims

1. Liquid crystal medium comprising

- a chiral component, component A;
- a bimesogenic component, component B;
- a dielectrically positive component, component C; and/or a dielectrically negative component, component D; and
- optionally a dielectrically neutral component, component E;

characterized in that

said component B comprises a bimesogenic compound having a non-symmetric structure.

2. Liquid crystal medium according to claim 1, characterized in that it comprises

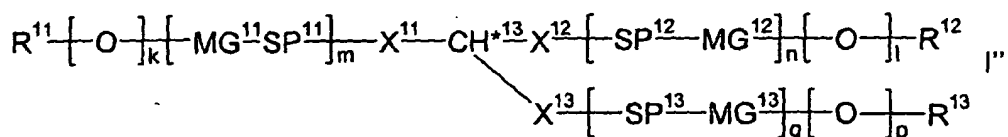
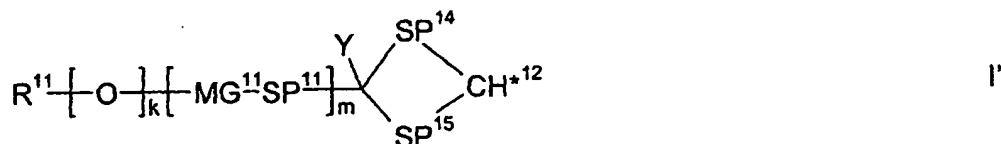
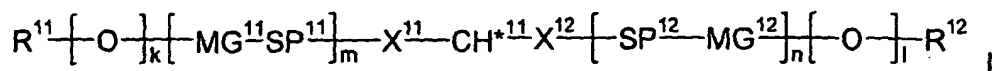
- a dielectrically neutral component, component E.

3. Liquid crystal medium according to any one of the preceding claims, characterized in that

said component B comprises a bimesogenic compound having a non-symmetric structure and an odd number of atoms in the spacer group between the two mesogenic units.

4. Liquid crystal medium according to any one of the preceding claims, characterized in that it comprises both a dielectrically negative component, component D and a dielectrically neutral component, component E.

5. Liquid crystal medium according to any one of the preceding claims 1 to 4, **characterized in that** said component A comprises one or more compounds selected from the group of formulae I, I' and I''



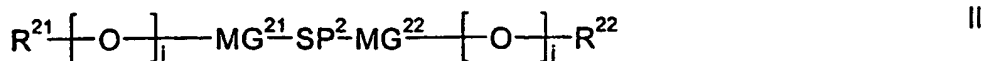
wherein

Y, R ¹¹ , R ¹² and R ¹³	are each, independently of one another, F, Cl, CN, NO ₂ , NCS, SCN, OCN, a straight-chain or branched alkyl group with 1 to 25 C atoms which may be unsubstituted, mono- or polysubstituted by halogen or CN, it being also possible for one or more non-adjacent CH ₂ groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, -N(CH ₃)-, -CO-, -COO-, -OCO-, -OCOO-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CH-, =CF=CF- or -C≡C- in such a manner, that oxygen atoms are not linked directly to one another, or, in case they are not linked to an O atom, H;
SP ¹¹ , SP ¹² and SP ¹³	are each, independently of one another, a divalent spacer group comprising 1 to 40, preferably 4 to 20, C atoms, preferably an alkylene group, it being also possible for one or more CH ₂ groups in the spacer groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, -N(CH ₃)-, -CO-, -COO-, -OCO-, -OCOO-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CH-, -CF=CF-, -CF ₂ - or -C≡C- in such a manner, that oxygen atoms are not linked directly to one another;
SP ¹⁴ and SP ¹⁵	are each, independently of one another, a divalent spacer group comprising 1 to 40, preferably 4 to 20, C atoms;
X ¹¹ , X ¹² and X ¹³	are each, independently of one another, -O-, -S-, -CO-, -COO-, -OCO-, -OCOO-, -CO-NH-, -NH-CO-, -CH ₂ CH ₂ -, -OCH ₂ -, -CH ₂ O-, -SCH ₂ -, -CH ₂ S-, -CF=CF-, -CH=CH-, -OCO-CH=CH-, -C≡C- or a single bond;
k, l, n, m, p and q	are each, independently of one another, 0 or 1,
m+n+q	is 1, 2 or 3;
MG ¹¹ , MG ¹² and MG ¹³	are each, independently of one another, a mesogenic group;

CH*¹¹ and CH*¹² are, independently from each other, a chiral, bivalent group; and

CH*¹³ is a chiral, trivalent group.

6. Liquid crystal medium according to any one of the preceding claims, **characterized in that** it said component B comprises one or more compounds of formula II



wherein

R²¹ and R²² are each, independently of one another, F, Cl, CN, NO₂, NCS, SCN, OCN, a straight-chain or branched alkyl group with 1 to 25 C atoms which may be unsubstituted, mono- or polysubstituted by halogen or CN, it being also possible for one or more non-adjacent CH₂ groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, -N(CH₃)-, -CO-, -COO-, -OCO-, -OCOO-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CH-, -CF=CF- or -C≡C- in such a manner, that oxygen atoms are not linked directly to one another, or, in case they are not linked to an O atom, H;

MG²¹ and MG²² are each, independently of one another, a mesogenic group;

SP² is a divalent spacer group comprising 1 to 40, preferably 3 to 20, C atoms, preferably an alkylene group, it being also possible for one or more CH₂ groups in the spacer groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, -N(CH₃)-, -CO-, -COO-, -OCO-, -OCOO-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CH-, -CF=CF-, -CF₂- or -C≡C- in such a manner, that oxygen atoms are not linked directly to one another;

i and j are, independently of each other, 0 or 1;

whereby the moiety R²¹-[O]_i-MG²¹- is different from the moiety R²²-[O]_j-MG²²-.

7. Liquid crystal device, **characterized in that** it comprises a liquid crystal medium according to at least one of claims 1 to 6.

8. Liquid crystal device according to claim 7, **characterized in that** it is an electro-optical display.

9. Liquid crystal device according to any one of claims 7 or 8, **characterized in that** it comprises a display that comprises

- a pair of substrates
 - each substrate bearing one or more electrodes; and
 - one substrate bearing an orientation layer for planar alignment of liquid crystals or being otherwise treated for planar orientation of liquid crystals; and
 - the other substrate bearing an orientation layer for homeotropic alignment of liquid crystals or being otherwise treated for homeotropic alignment of liquid crystals

and

- a liquid crystal material comprising the liquid crystal medium according to any one of claims 1 to 6; whereby said material is aligned in a uniformly lying helix structure with a helical pitch of 500 nm or less.

10. Liquid crystal device according to any one of claims 7 to 9, **characterized in that** said liquid crystal material exhibits

a blue phase.

11. Liquid crystal device according to any one of claims 7 to 10, **characterized in that** the orientation of said liquid crystal material in said uniformly lying helix structure is achieved by application of an alternating electrical field at a temperature at which the liquid crystal material is in the blue phase.

12. Use of a liquid crystal medium according to at least one of claims 1 to 6 in a liquid crystal device.



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EUROPEAN SEARCH REPORT

Application Number
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